claims in U.S. Published Application No. 2002/0158193 (U.S. Patent Application No.10/074,561, now U.S. Patent No. 6,819,426 to Sezginer et al.). Pending claims 78 - 133 were copied into the present application on August 2, 2005 as substantial copies of selected issued claims of U.S. Patent No. 6,772,084 to Bischoff et al. Pending claims 134 - 204 were copied into the present application on October 11, 2005 as substantial copies of selected issued claims of U.S. Patent No. 6,804,005 to Bischoff et al. While each of the amendments copying the claims identified the application and patents from which the claims were copied, no request for declaration of an interference was filed and is not being filed herein. Notwithstanding, the Applicants respectfully provide the requested information described under 37 C.F.R. § 41.202 below.

Office Action Mailed June 8, 2006

In addition to the above comments, the Applicants respectfully also respond to the June 8, 2006 request for information regarding the additional pending claims 205 - 259, with the following comments. The document filed on February 7, 2006 was a Power of Attorney, not an amendment, nor a response to the December 27, 2005 Office Action. Pending claims 205 - 259 were copied into the present application on February 15, 2006 as substantial copies of the issued claims of U.S. Patent No. 6,855,464 to Niu et al. The February 15, 2006 amendment noted that claims 205 - 259 were being added to avoid any question of compliance with 35 USC § 135(b) should the Applicants decide, after completing their analysis, that the subject claims are patentable, that the present application is directed to the same invention as those clams, and that an interference is appropriate. No request for declaration of an interference was filed.

REMARKS

The present application ("the '153 application") was filed October 30, 2003 as a continuation of U.S. Patent Application Serial No. 09/833,084, filed April 10, 2001 (now abandoned). The present application published November 18, 2004 as U.S. Published Patent Application No. 2004/0229471.

The present application was subject to a restriction requirement, mailed July 27, 2005. Applicants responded on August 26, 2005, electing claims 55 - 62 and withdrawing from examination claims 63 - 77. An Office Action was mailed December 27, 2005, requesting

information under 37 C.F.R. § 41.202 regarding claims 78 - 204. A further Office Action was mailed June 8, 2006, requesting information under 37 C.F.R. § 41.202 regarding claims 78 - 259. The Applicants provide the requested information in the present Response as best they can, given the fact that they have not to date requested declaration of an interference.

The Applicants want to advise the Examiner that claims 55 - 62 are substantially identical to, and have been copied from, claims 1 - 5, 7, 10, and 11, respectively, of U.S. Published Application No. 2002/0158193 (U.S. Patent Application No.10/074,561, now U.S. Patent No. 6,819,426 to Sezginer et al.) ("the '193 published application"). Claims 57, 58, and 61 are substantially identical to issued claims 1, 2, and 8 of U.S. Patent No. 6,819,426 to Sezginer et al. Claims 78 - 133 are substantially identical to, and have been copied from, claims 1 - 9, 11 - 13, 15 - 18, 28 - 30, 32 - 34, 36, 38, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 68 - 72, 74 - 81, 83 - 85, 87 - 89, and 91, respectively, of U.S. Patent No. 6,772,084 to Bischoff et al. ("the '084 patent"). Pending claims 134 - 204 are substantially identical to, and have been copied from, claims 1 - 3, 8, 13, 9, 10, 18 - 23, 27 - 37, 41 - 45, 49, 52 - 57, 61 - 65, 69, 74 - 76, 78, 80 - 84, 88 - 95, 99, 101 - 104, 106 - 108, and 114 - 116, respectively, of U.S. Patent No. 6,804,005 to Bischoff et al. ("the '005 patent"). Claims 205 - 235 are substantially identical to, and have been copied from, claims 1 - 31, respectively, of U.S. Patent No. 6,855,464 to Niu et al. ("the '464 patent"). Claims 236 - 259 are substantially identical to, and have been copied from, claims 1 - 10, 15 - 19, 21 - 28, and 31, respectively, of the '464 patent.

Thus, claims 55 - 62 and 78 - 259 are pending in the present application, claims 63 - 77 having been withdrawn from consideration pursuant to a restriction requirement. Exemplary description for claims 55 - 62 and 78 - 259 in the present application is presented in Appendix A for the convenience of the Examiner, with citations to the '153 application as published on November 18, 2004.

37 C.F.R. § 41.202

Applicants present the current paper in response to two requests for information by the Patent Office, mailed December 27, 2005 and June 8, 2006. Applicants respectfully note that they have not, to date and as noted in their February 15, 2006 Amendment, completed their analysis that the subject claims are patentable, that the present application is directed to the same invention as these claims, and that an interference is appropriate. Accordingly,

Applicants have not requested declaration of an interference and supply the present information only in response to the requests made by the Examiner in the December 27, 2005 and June 8, 2006 Office Actions.

Table of Appendices

Appendix A: Exemplary written description support in the '153 specification, as filed and as published, for the present pending claims 55 - 62 and 78 - 259 as copied from the '193 published application, the '084 patent, the '005 patent, and the '464 patent.

Appendix B: Presentation of a proposed count in the alternative.

Appendix C: Claims 1, 2, and 8 of the '426 patent.

Appendix D: Claims 1 - 9, 11 - 13, 15 - 18, 28 - 30, 32 - 34, 36, 38, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 68 - 72, 74 - 81, 83 - 85, 87 - 89, and 91 of the '084 patent.

Appendix E: Claims 1 - 3, 8 - 10, 13, 18 - 23, 27 - 37, 41 - 45, 49, 52 - 57, 61 - 65, 69, 74 - 76, 78, 80 - 84, 88 - 95, 99, 101 - 104, 106 - 108, and 114 - 116 of the '005 patent.

Appendix F: Claims 1 - 31 of the '464 patent.

Appendix G: A side-by-side comparison of the first alternative of the count compared to one claim of the '084 patent and one claim of the '153 application.

Appendix H: A side-by-side comparison of the second alternative of the count compared to one claim of the '084 patent and one claim of the '153 application.

(1) Identification of the Patents With Which the Applicants Seek an Interference

The patents which claim subject matter which interferes with subject matter claimed in the present application are U.S. Patent No. 6,819,426 to Fitzgerald, et al. for "Overlay Alignment Metrology Using Diffraction Gratings;" U.S. Patent No. 6,772,084 to Bischoff et al. for "Overlay Measurements Using Periodic Gratings;" U.S. Patent No. 6,804,005 to Bischoff et al. for "Overlay Measurements Using Zero-Order Cross Polarization Measurements;" and U.S. Patent No. 6,855,464 to Niu et al. for "Grating Test Patterns and Methods for Overlay Metrology."

(2) (a) Identification of all Claims the Applicants Believe Interfere

The Applicants believe that claims 1, 2, and 8 of the '426 patent interfere, respectively, with claims 57, 58, and 61 of the '153 application. The asserted interfering claims of the '426 patent are presented in Appendix C for the convenience of the Examiner. The Applicants believe that claims 1 - 9, 11 - 13, 15 - 18, 28 - 30, 32 - 34, 36, 38, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 63, 68 - 72, 74 - 81, 83 - 85, 87 - 89, and 91 of the '084 patent interfere, respectively, with claims 78 - 133 of the '153 application. The asserted interfering claims of the '084 patent are presented in Appendix D for the convenience of the Examiner. The Applicants believe that claims 1, 3, 8, 13, 9, 10, 18 - 23, 27 - 37, 41 - 45, 49, 52 - 57, 61 - 65, 69, 74 - 76, 78, 80 - 84, 88 - 95, 99, 101 - 104, 106 - 108, and 114 - 116 of the '005 patent interfere, respectively, with claims 134 - 204 of the '153 application. The asserted interfering claims of the '005 patent are presented in Appendix E for the convenience of the Examiner. The Applicants believe that claims 1 - 31 of the '464 patent interfere, respectively, with claims 205 - 235 of the '153 application. The Applicants believe that claims 1 - 10, 15 - 19, 21 - 28, and 31 of the '464 patent also interfere, respectively, with claims 236 - 259 of the '153 application. The asserted interfering claims of the '464 patent are presented in Appendix F for the convenience of the Examiner.

(b) Presentation of a Proposed Count

The interfering subject matter between the '153 application and each of the '426, '084, '005, and '464 patents relates to a system and method of obtaining overlay measurements for a semiconductor wafer, wherein a first grating and a second grating are formed on the wafer, and wherein a diffraction signal of the first and second gratings is measured for determining a misalignment between the first and second gratings and comparing the diffraction signal to determine a possible misalignment during the manufacture of the wafer. See the '153 published application at abstract and paragraphs 0001, 0002, 0003, 0008, and 0038. See the '426 patent at abstract, Col. 1, lines 13 - 26; Col. 6, line 63 - Col. 7, line 1; Col. 7, lines 23 - 50. See the '084 patent at abstract; Col. 1, lines 7 - 10 and lines 36 - 48; Col. 4, line 62 - Col. 5, line 14. See the '005 patent at abstract; Col. 1, lines 9 - 13 and lines 39 - 49; Col. 4, line 58 - Col. 5, line 10. See the '464 patent at abstract; Col. 1, lines 14 - 18; Col. 2, lines 17 - 25; Col. 5, lines 55 - 67. Attached Appendix B sets forth a proposed count of the interfering subject matter, in the alternative. Appendix B shows the count as

consisting of claim 18 of the '084 patent, which corresponds to claim 93 of the '153 application. While a method claim has been proposed as the count, the Applicants note that the interfering claims also include system claims. While the Applicants believe that the method claims and the system claims are directed to the same subject matter as evidenced, at least in part, by the lack of any restriction requirement in the claims, a second count directed to system claims can be proposed should the Examiner believe such a second count would be appropriate.

(c) Showing How the Claims of the '426, '084, '005, and '464 Patents Correspond to the Proposed Count

The '426 Patent

Independent claims 1, 2, and 8 of the '426 patent are believed to correspond to the proposed count. The proposed count and independent claims 1, 2, and 8 of the '426 patent are directed to a method of obtaining overlay measurements for a semiconductor wafer by forming first and second sets of gratings on the wafer, wherein the sets of gratings are intended to be formed on the wafer with an intended alignment. A diffraction signal from the sets of gratings is measured, and a misalignment between the sets of gratings is determined based on the measured diffraction signal. The measured diffraction signal is compared to a generated set of diffraction signals as a reference or optical model. Accordingly, claims 1, 2, and 8 of the '426 patent include all the features of the count, and also include several features that would have been obvious to the person of ordinary skill in view of the count. Therefore, claims 1, 2, and 8 of the '426 patent correspond to the proposed count.

The '084 Patent

Dependent claim 18 of the '084 patent corresponds to the proposed count because claim 18 is identical to one alternative of the proposed count. Independent claim 1 and intervening dependent claim 12, from which claim 18 ultimately depends, would be obvious in view of claim 18; and, therefore, claims 1 and 12 correspond to the count. Dependent claim 79 of the '084 patent corresponds to the proposed count because claim 79 recites a system for performing the method of claim 18. Independent claim 70 and intervening dependent claims 77 and 78, from which claim 79 ultimately depends, would be obvious in view of claim 79; and, therefore, claims 70, 77, and 78 correspond to the count.

In addition to claim 1, independent claims 38 and 55 of the '084 patent are believed to correspond to the proposed count. Claims 38 and 55 recite various embodiments of the method of obtaining overlay measurements for a semiconductor wafer, wherein any differences between claims 38 and 55 and claim 1 are obvious variations known to persons of skill in the art. For example, claim 1 recites the first set of gratings are formed using a first mask and the second set of gratings are formed using a second mask; and claim 38 recites the first and second set of gratings are formed using separate masks. Dependent claims 2 - 9, 11, 13, 15 - 17, 28 - 30, 32 - 34, 36, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 63, 68, and 69 are believed to correspond to the count. Claims 2 - 9, 11, 13, 15 - 17, 28 - 30, 32 - 34, 36, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 68, and 69 depend from independent claims 1, 38, and 55 and include all the features of these claims plus additional features that would have been obvious to the person of ordinary skill in view of the count.

Dependent claims 71, 72, 74 - 76, 81, 83, and 84 are believed to correspond to the proposed count. Claims 71, 72, 74 - 76, 81, 83, and 84 depend from claim 70, which corresponds to the count, and include all the features of this claim plus additional features that would have been obvious to the person of ordinary skill in view of the count. Independent claim 85 of the '084 patent is believed to correspond to the proposed count because claim 85 recites a computer-readable storage medium containing computer instructions for performing the method of claim 1, which corresponds to the count. Dependent claims 87 - 89 and 91 are believed to correspond to the proposed count. Claims 87 - 89 and 91 depend from independent claim 85, which corresponds to the count, and include all the features of this claim plus additional features that would have been obvious to the person of ordinary skill in view of the count.

Therefore, claims 1 - 9, 11 - 13, 15 - 18, 28 - 30, 32 - 34, 36, 38, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 68 - 72, 74 - 81, 83 - 85, 87 - 89, and 91 of the '084 patent correspond to the proposed count.

The '005 Patent

Independent claims 1, 36, and 57 are believed to correspond to the proposed count. For example, claim 1 recites a method of obtaining overlay measurements for a semiconductor wafer, including the steps of forming a period grating on a wafer, the grating having a first and second set of gratings by use of a first and a second mask; obtaining

polarization measurements of the first and second sets of gratings; and determining any overlay error between the first and second masks based on the measurements. As can be seen from Appendix B, that portion of the count derived from claim 1 of the '084 patent discloses the features recited in claim 1 of the '005 patent, with any variations being obvious to the person of ordinary skill in the art. Accordingly, independent claims 1, 36, and 57 should be designated as corresponding to the count. Dependent claims 2 - 3, 8, 13, 9, 10, 18 - 23, 27 - 35, 37, 41 - 45, 49, 52 - 56, 61 - 65, and 69 are believed to correspond to the proposed count. Claims 2 - 3, 8, 13, 9, 10, 18 - 23, 27 - 35, 37, 41 - 45, 49, 52 - 56, 61 - 65, and 69 depend from claims 1, 36, and 57, which are asserted as corresponding to the count, and include all the features of these claims plus additional features that would have been obvious to the person of ordinary skill in view of the count.

Independent claim 74 is believed to correspond to the proposed count because claim 74 recites a system for performing the method of claim 1, which corresponds to the count. Dependent claims 75, 76, 78, 80 - 84, 88 - 95, 99, 101, and 102 are believed to correspond to the count. Claims 75, 76, 78, 80 - 84, 88 - 95, 99, 101, and 102 depend from claim 74, which corresponds to the count, and include all the features of this claim plus additional features that would have been obvious to the person of ordinary skill in view of the count.

Independent claim 103 is believed to correspond to the proposed count because claim 103 recites a computer-readable storage medium containing computer executable instructions for performing the method of claim 1, which corresponds to the proposed count. Dependent claims 104, 106 - 108, and 114 - 116 are believed to correspond to the proposed count. Claims 104, 106 - 108, and 114 - 116 depend from claim 103, which corresponds to the count, and include all the features of this claim plus additional features that would have been obvious to the person of ordinary skill in view of the count.

Therefore, claims 1 - 3, 8 - 10, 13, 18 - 23, 27 - 37, 41 - 45, 49, 52 - 57, 61 - 65, 69, 74 - 76, 78, 80 - 84, 88 - 95, 99, 101 - 104, 106 - 108, and 114 - 116 of the '005 patent correspond to the proposed count.

The '464 Patent

Independent claims 1 and 16 are believed to correspond to the proposed count. For example, claim 1 recites a method of obtaining overlay measurements, including forming a first and a second grating test pattern using a first and a second mask; wherein the first and

second grating test patterns have the same periodicity; measuring the first and second grating test patterns and measuring the alignment of the second mask to the first mask based on the measurement of the first and second grating test patterns. As can be seen from Appendix B, that portion of the count derived from claim 1 of the '084 patent discloses the features recited in claim 1 of the '464 patent, with any variations being obvious to the person of ordinary skill in the art. Accordingly, independent claims 1 and 16 should be designated as corresponding to the proposed count. Dependent claims 2 - 15 and 17 - 20 are believed to correspond to the proposed count. Claims 2 - 15 and 17 - 20 depend from claims 1 and 16, which are asserted as corresponding to the count, and include all the features of these claims plus additional features that would have been obvious to the person of ordinary skill in view of the count.

Independent claim 21 is believed to correspond to the proposed count because claim 21 recites a structure formed on a semiconductor wafer for performing the method of claim 1, which corresponds to the count. Dependent claims 22 - 31 are believed to correspond to the proposed count. Claims 22 - 31 depend from claim 21, which corresponds to the count, and include all the features of this claim plus additional features that would have been obvious to the person of ordinary skill in view of the count.

Therefore, claims 1 - 31 of the '464 patent correspond to the proposed count.

(d) <u>Showing How the Claims of the '153 Application Correspond to The Proposed Count</u>

Claims 57, 58, and 61 of the '153 application are substantially identical to issued claims 1, 2, and 8, respectively, of the '426 patent. Claims 78 - 133 are substantially identical to, and have been copied from, claims 1 - 9, 11 - 13, 15 - 18, 28 - 30, 32 - 34, 36, 38, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 63, 68 - 72, 74 - 81, 83 - 85, 87 - 89, and 91, respectively, of the '084 patent. Pending claims 134 - 204 are substantially identical to, and have been copied from, claims 1, 3, 8, 13, 9, 10, 18 - 23, 27 - 37, 41 - 45, 49, 52 - 57, 61 - 65, 69, 74 - 76, 78, 80 - 84, 88 - 95, 99, 101 - 104, 106 - 108, and 114 - 116, respectively, of the '005 patent. Claims 205 - 235 are substantially identical to, and have been copied from, claims 1 - 31, respectively, of the '464 patent. Claims 236 - 259 are substantially identical to, and have been copied from, claims 1 - 10, 15 - 19, 21 - 28, and 31, respectively, of the '464 patent.

Accordingly, claims 57, 58, 61, and 78 - 259 correspond to the count for the same reasons as discussed above as regards the asserted claims of the '426, '084, '005, and '464

patents.

(e) The Patents and the '153 Application use Different Terms to Describe the Same Invention

The '426, '084, '005, and '464 patents and the '153 application are all directed to a system and method of obtaining overlay measurements for a semiconductor wafer, wherein a first grating and a second grating are formed on the wafer, and wherein a diffraction signal of the first and second gratings is measured for determining a misalignment between the first and second gratings and comparing the diffraction signal to determine a possible misalignment during the manufacture of the wafer.

For example, claim 92 of the '153 application, which was substantially copied from claim 17 of the '084 patent, recites the set of diffraction signals being generated using modeling. Similarly, claim 140 of the '153 application, which was substantially copied from claim 13 of the '005 patent, recites the reference signal being generated using modeling. These features are disclosed in the respective patents at Col. 8, lines 7 - 22 and Col. 10, lines 17 - 33, wherein the relationship between misalignment and the measured diffraction signal can be stored in various formats, including a data table, for subsequent comparison. Similarly, the '153 application discloses at paragraphs 8 and 64 that the misalignment or overlay misregistration between the structures can be determined from the measured signal as compared with a reference signal from a database.

As another example where different terms are used to describe the same elements, claims 12, 38, 55, and 85 of the '084 patent recite generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings. This feature is discussed in the '084 patent at least at Col. 5, line 54 - Col. 6, line 41 and Col. 8, lines 7 - 11, where a signal is directed onto a set of gratings and the resultant diffraction signal is measured for possible misalignment. The relationship between the diffraction signal and any misalignment can be determined by referencing a data table. Similarly, the '153 application discloses at least at paragraphs 0059, 0063, and 0076 a similar technique for measuring misalignment by providing a radiation beam onto periodic structures, with diffracted radiation from the illuminated structures providing an output signal. The diffracted radiation output signal is compared against a reference signal from a database to determine misalignment.

All the features recited in the '153 claims are either disclosed in the originally filed

'153 application or would have been obvious to the person of ordinary skill at the time the '153 application was filed. To assist the Examiner in this regard, Applicant attaches Appendix A. Appendix A is a chart providing an element-by-element recitation of claims 55 - 62 and 78 - 259 of the '153 application and an indication of at least some of the passages in the originally filed application where, at the very least, the claims find description. The citations are to the '153 application as published November 18, 2004.

(3) (a) Claim Chart Comparing at Least One Claim of the Patents and One Claim of the '153 Application to the Count

Appendix G is a claim chart comparing claim 18 of the '084 patent and claim 93 of the '153 application with the first alternative of the proposed count in independent form.

Appendix H is a claim chart comparing claim 18 of the '084 patent and claim 93 of the '153 application with the second alternative of the proposed count in independent form.

(b) Explanation Why the Claims Interfere Within the Meaning of 37 CFR §41.203(a)

Dependent claim 93 of the '153 application, having been copied from claim 18 of the '084 patent, is substantially identical to claim 18 of the '084 patent and therefore is directed to the same subject matter as claim 18 of the '084 patent. Therefore, claim 93 of the '153 application includes all and only the material features recited in claim 18 of the '084 patent. Accordingly, if the '153 application is viewed as prior art to the '084 patent, claim 93 of the '153 application would anticipate at least claim 18 of the '084 patent because the two claims recite matching features. Correspondingly, if the '084 patent is viewed as prior art to the '153 application, claim 18 of the '084 patent would anticipate at least claim 93 of the '153 application because the two claims recite matching features. Therefore, claim 93 of the '153 application and claim 18 of the '084 patent interfere within the meaning of 37 CFR § 41.203(a).

(4) Explanation Why the Applicants Will Prevail On Priority

The '153 Abdulhalim application is entitled to priority back to U.S. Patent Application No. 09/833,084, filed April 10, 2001. In particular, the '153 application, as filed October 30, 2003, is a continuation of U.S. Patent Application No. 09/833,084, filed April 10,

2001 (which is now abandoned). Therefore, the specification of the '153 application is identical to the specification of the '084 application filed April 10, 2001 and has priority to at least April 10, 2001.

The '426 Sezginer et al. patent claims priority back to U.S. Provisional Application No. 60/268,485, filed February 12, 2001. In particular, the '426 patent, filed February 12, 2002 as U.S. Patent Application No. 10/074,561, asserts priority to U.S. Provisional Application No. 60/322,219, filed September 14, 2001; to U.S. Provisional Application No. 60/295,111, filed June 1, 2001; and to U.S. Provisional Application No. 60/268,485, filed February 12, 2001. Therefore, at best, the '426 Sezginer et al. patent claims to have a priority date no earlier than February 12, 2001. However, the Applicants can show conception of the subject matter of the count prior to February 12, 2001 and diligence to a constructive reduction to practice on or about April 10, 2001.

The '084 Bischoff et al. application was filed January 31, 2002, with no prior applications to which priority is claimed.

The '005 Bischoff et al. application was filed May 2, 2002, with no prior application to which priority is claimed.

The '464 Niu et al. patent claims priority back to U.S. Application Serial No. 09/794,686, filed February 27, 2001. In particular, the '464 patent, filed December 17, 2003 as U.S. Application Serial No. 10/739,660, asserts priority to U.S. Application Serial No. 09/794,686, filed February 27, 2001 (which issued as U.S. Patent Serial No. 6,699,624). Therefore, at best, the '464 Niu et al. patent claims to have a priority date no earlier than February 27, 2001. However, the Applicants can show conception of the subject matter of the count prior to February 12, 2001 and diligence to a constructive reduction to practice on or about April 10, 2001.

(5) Claim Chart of Added Claims Showing the Written Description for Each Claim in the Applicants' Specification

Appendix A is a claim chart which shows examples of the written description in the Applicants' specification supporting each of the features recited in claims 55 - 62 and 78 - 259.

(6) Chart Showing Where the Disclosure Provides a Constructive Reduction to Practice Within the Scope of the Interfering Subject Matter

The specification of the '153 application was first filed April 10, 2001, thereby evidencing a constructive reduction to practice on at least that date. Appendix A is a claim chart showing examples of the constructive reduction to practice in Applicants' disclosure for each of the features recited in claims 57, 58, 61, and 78 - 259 that are asserted herein to be interfered by claims 1, 2, and 8 of the '426 Sezginer et al. patent; claims 1 - 9, 11 - 13, 15 - 18, 28 - 30, 32 - 34, 36, 38, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 68 - 72, 74 - 81, 83 - 85, 87 - 89, and 91 of the '084 Bischoff et al. patent; claims 1 - 3, 8 - 10, 13, 18 - 23, 27 - 37, 41 - 45, 49, 52 - 57, 61 - 65, 69, 74 - 76, 78, 80 - 84, 88 - 95, 99, 101 - 104, 106 - 108, and 114 - 116 of the '005 Bischoff et al. patent; and claims 1 - 31 of the '464 Niu et al. patent.

(7) The Requirements of 35 USC § 135(b) are Satisfied

The '153 Abdulhalim application was filed with the U.S. Patent and Trademark Office on October 30, 2003, with a preliminary amendment substantially copying published claims 1 - 5, 7, 10 - 13, 14, 16, 18 - 22, 24, and 26 - 30 of U.S. Application No. 10/074,561, said application having published on October 31, 2002. Published claims 3, 4, and 10 subsequently issued, among other claims, on November 16, 2004 in U.S. Patent No. 6,819,426 to Sezginer et al. as issued claims 1, 2, and 8. Claims 1, 2, and 8 of the '426 patent were timely copied into the '153 application within a year of the publication of these claims, thereby satisfying 35 USC § 135(b)(2).

On August 2, 2005, claims 1 - 9, 11 - 13, 15 - 18, 28 - 30, 32 - 34, 36, 38, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 68 - 72, 74 - 81, 83 - 85, 87 - 89, and 91 of U.S. Patent No. 6,772,084 to Bischoff et al. were substantially copied into the '153 application. The '084 patent issued August 3, 2004 with claims that were directed to different subject matter than the claims that earlier published under the '084 patent application. Accordingly, the requirements of 35 USC § 135(b)(1) have been satisfied.

On October 11, 2005, claims 1 - 3, 8 - 10, 13, 18 - 23, 27 - 37, 41 - 45, 49, 52 - 57, 61 - 65, 69, 74 - 76, 78, 80 - 84, 88 - 95, 99, 101 - 104, 106 - 108, and 114 - 116 of U.S. Patent No. 6,804,005 to Bischoff et al. were substantially copied into the '153 application. The '005 patent issued October 12, 2004 with claims that were directed to substantially the same subject matter as published under the '005 patent application on November 6, 2003.

However, because the claims were copied into the '153 application, which has a filing date of October 30, 2003, the requirements of 35 USC § 135(b)(2) have been satisfied.

On February 15, 2006, claims 1 - 31 of U.S. Patent No. 6,855,464 to Niu et al. were substantially copied into the '153 application. The '464 patent issued February 15, 2005 with claims that were directed to substantially the same subject matter as published under the '464 patent application on July 15, 2004. However, because the claims were copied into the '153 application, which has a filing date of October 30, 2003, the requirements of 35 USC § 135(b)(2) have been satisfied.

CONCLUSION

Claims 57, 58, 61, and 78 - 259 were substantially copied from claims 1, 2, and 8 of the '426 Sezginer et al. patent; claims 1 - 9, 11 - 13, 15 - 18, 28 - 30, 32 - 34, 36, 38, 39, 43, 44, 52, 53, 55, 57, 58, 60, 62, 63, 68 - 72, 74 - 81, 83 - 85, 87 - 89, and 91 of the '084 Bischoff et al. patent; claims 1 - 3, 8 - 10, 13, 18 - 23, 27 - 37, 41 - 45, 49, 52 - 57, 61 - 65, 69, 74 - 76, 78, 80 - 84, 88 - 95, 99, 101 - 104, 106 - 108, and 114 - 116 of the '005 Bischoff et al. patent; and claims 1 - 31 of the '464 Niu et al. patent, as published and as allowed, and within the time limits of 35 USC § 135(b).

If any additional fees are required in connection with this Response, please charge the same to our Deposit Account No. 50-2518.

Respectfully submitted,

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Appendix A
Citations to Exemplary Description in the '153 Abdulhalim Application*

'153 Abdulhalim Claims	Description for Claimed Features in the '153 Abdulhalim Application
55. A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device… The invention also relates to a method of making overlying or interlaced targets. Paragraph 8 - The invention also relates to a method of detecting misalignment between two layers of a device.
forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, zero or more layers of other materials separating layers A and B, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B;	Paragraph 6 - The two periodic structures overlie or are interlaced with each other. The layers or periodic structures may be at the same or different heights. In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Figs. 2a and 4a
observing the overlaid diffraction gratings using an optical instrument capable of measuring reflectance as a function of wavelength or polarization of illumination and detection using the instrument, or capable of measuring ellipsometric parameters as a function of wavelength of the illumination and detection; and	Paragraph 8 - The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal. Paragraph 65 - The ellipsometric parameter values were obtained for zero-order diffracted radiation using an incident radiation beam 81 at an angle of 25° to the wafer surface. The ellipsometric parameters, Tan[Ψ] and Cos[Δ], were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. Paragraph 70 - Polarization scans from incident polarization angles of 0° to 90° were performed to generate the graphical plots in Figs. 13 and 14. Fig. 14 shows the differential intensity as a function of incident polarization angle at different overlay misregistration (-50 nm, -35 nm, -15 nm, 0 nm, 15 nm, 35 nm, and 50nm). … Similar graphical plots were obtained at different wavelengths.
determining the offset between the gratings from the measurements from the optical instrument using an optical model, wherein the optical model accounts for the diffraction of the electromagnetic waves by the gratings and the interaction of the gratings with each other's diffracted field.	Paragraph 8 - The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed.

* - The cited passages are an indication of where in the originally filed '153 Abdulhalim Application, at the very least, the claims find exemplary description. Applicants reserve the right to identify and demonstrate additional description if necessary or desirable.

56. The method of claim 55 wherein any layers between the grating in layer A and the grating in layer B are at least partially transparent at the wavelength range of the optical instrument.	Paragraph 33 - FIGS. 4a and 4b show alternative embodiments. In one embodiment, FIG. 4a illustrates a first periodic structure 13 of oxide having a trapezoidal shape on a first layer 31 of silicon substrate and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 of silicon is etched, and shallow trench isolation ("STI") oxide is deposited in the spaces of the etched silicon. The lines of STI oxide form the first periodic structure 13. An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13.
57. The method of claim 55 wherein at least one layer between the grating in layer A and the grating in layer B is opaque in the wavelength range of the optical instrument, and the presence of the grating in layer A causes a grating-shaped topography on the surface of the opaque layer.	Paragraph 33 - FIGS. 4a and 4b show alternative embodiments. In one embodiment, FIG. 4a illustrates a first periodic structure 13 of oxide having a trapezoidal shape on a first layer 31 of silicon substrate and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 of silicon is etched, and shallow trench isolation ("STI") oxide is deposited in the spaces of the etched silicon. The lines of STI oxide form the first periodic structure 13. An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. Paragraph 34 - In another embodiment, FIG. 4b illustrates a first periodic structure 13 of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
58. The method of claim 55 wherein the optical model represents the electromagnetic field in the gratings and in the layers between the gratings as a sum of more than one diffracted orders.	Paragraph 9 - An advantage of this method is the use of only one incident radiation beam. Another advantage of this method is the high sensitivity of zero-order and first-order diffracted light to the overlay misregistration between the layers. In particular, properties which exhibited high sensitivity are intensity, phase and polarization properties of zero-order diffraction; differential intensity between the positive and negative first-order diffraction; differential phase between the positive and negative first-order diffraction; and differential polarization between the positive and negative first-order diffraction. These properties also yielded linear graphs when plotted against the overlay misalignment. This method can be used to determine misalignment on the order of nanometers.

59. The method of claim 55 wherein offset is determined by: calculating, according to a model of a wafer sample, the optical response of the sample with said two overlapping gratings, the model of the sample taking into account parameters of the sample including any of the overlay misalignment of layers A and B, and a profile parameter of the grating structures; and	Paragraph 8 - The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 65 - Figs. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. Figs. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of Fig. 2a with the optical system of Fig. 9a. The calculations were performed using the Lambda SW.... The ellipsometric parameter values were obtained for zero-order diffracted radiation using an incident radiation beam 81 at an angle of 25° to the wafer surface.
minimizing the difference between the calculated and measured optical responses.	Paragraph 61 - The imaging and focusing of the optical system 120 is verified using the vision and pattern recognition system 115 in the same way as the imaging and focusing of the optical system 110 is in FIG. 10. In one embodiment, the beam splitter 113 splits off radiation 89 to reference light detection unit 137, which detects fluctuations of the light source 101. The reference light detection unit 137 communicates information 86 concerning intensity fluctuation of source 101 to the signal processing and computing unit 109. The signal processor 109 normalizes the output signal 85 using fluctuation information 86. Paragraph 62 - Optical systems 100, 110, 120 can be integrated with a deposition instrument 200 to provide an integrated tool, as shown in FIGS. 9b, 10b and 11b. The deposition instrument 200 provides the overlying or interlaced periodic structures on wafer 91 in step 301. Optical systems 100, 110, 120 obtains misalignment information from the wafer 91 in step 302. The signal processor 109 of optical systems 100, 110, 120 provides the misalignment to the deposition tool 200 in step 303. The deposition tool uses the misalignment information to correct for any misalignment before providing another layer or periodic structure on wafer 91 in step 301.
60. The method of claim 59 wherein at least a portion of the calculated optical response is retrieved from a pre-computed database.	Paragraph 45 - In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be

	determined by comparing the output signal 85 with the database.
61. The method of claim 55 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.	Paragraph 31- FIGS. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. The second selected width CD2 is less than the first selected width CD1. The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c. Figures 2a and 2b Figs. 5a, 5b and 6.
62. A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device... The invention also relates to a method of making overlying or interlaced targets. Paragraph 8 - The invention also relates to a method of detecting misalignment between two layers of a device.
forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a first patterned layer and a second diffraction grating is built into a second patterned layer, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B, and at least one of the first or second gratings having a repeating pattern consisting of at least two structures of substantially different lateral dimensions;	Paragraph 6 - The two periodic structures overlie or are interlaced with each other. The layers or periodic structures may be at the same or different heights. In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Figs. 2a and 4a
measuring the optical characteristics of the overlaid diffraction	Paragraph 8 - The overlying or interlaced periodic structures are illuminated by

gratings using an optical instrument with a spot size covering portions of the overlapping gratings; and	incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal. Paragraph 65 - The ellipsometric parameter values were obtained for zero-order diffracted radiation using an incident radiation beam 81 at an angle of 25° to the wafer surface. The ellipsometric parameters, Tan[Ψ] and Cos[Δ], were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. Paragraph 70 - Polarization scans from incident polarization angles of 0° to 90° were performed to generate the graphical plots in Figs. 13 and 14. Fig. 14 shows the differential intensity as a function of incident polarization angle at different overlay misregistration (-50 nm, -35 nm, -15 nm, 0 nm, 15 nm, 35 nm, and 50nm). ... Similar graphical plots were obtained at different wavelengths.
determining the offset between the gratings from the measured optical characteristics.	Paragraph 8 - The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 65 - Figs. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. Figs. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of Fig. 2a with the optical system of Fig. 9a. The calculations were performed using the Lambda SW.
78. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 6 – A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other. The invention also relates to a method of making overlying or

	interlaced targets. Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device.
forming a periodic grating on the wafer having:	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.
a first set of gratings,	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.
wherein the first set of gratings are formed on the wafer using a first mask, and	Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
a second set of gratings,	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.
wherein the second set of gratings are formed on the wafer using a second mask,	Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;	Paragraph 38; Figures 5a, 5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. Paragraph 40, Figures 5a, 5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L.sub.2+L.sub.3 and a line with width L.sub.1. Where c=b-L.sub.3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L.sub.1+L.sub.3 and a line with width L.sub.2. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a, the structure is most symmetric at zero overlay misregistration.
measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer;	Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal.
and	Paragraph 8 – The misalignment between the structures is determined from the

determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.	output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ...The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.
79. The method of claim 78, wherein the measured diffraction signal is a zero-order diffraction.	Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures.
80. The method of claim 79, wherein only the zero-order diffraction is measured.	Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffraction 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.
81. The method of claim 78, wherein the diffraction signal is measured using an optical metrology system.	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures.
82. The method of claim 81, wherein the optical metrology system includes an ellipsometer.	Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation

	83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
83. The method of claim 81, wherein the optical metrology system includes a reflectometer.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85.
84. The method of claim 78, wherein the diffraction signal is measured using an incident signal with a normal incidence angle.	Paragraph 75 - The incidence angle is 76.degree. in the Data 76 configuration, and the incidence angle is 0.degree. (normal) in the Data0 configuration. Paragraph 77; Figures 21-23 - FIGS. 21-23 were derived using the Data0 configuration. FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm). FIG. 23 shows the MSE variation as a function of overlay

<table>
<tr><td></td><td>misregistration. FIGS. 21 and 22 show the high sensitivity of the intensity of zero-order diffracted radiation to the overlay sign for a configuration using normal incident radiation on interlaced gratings.</td></tr>
<tr><td>85. The method of claim 78, wherein the diffraction signal is measured using an incident signal with an oblique incidence angle.</td><td>Paragraph 44; Figure 8 - The invention relates to a method to determine misalignment using diffracted light. FIG. 8 is a schematic view showing the diffraction of light from a grating structure 71. In one embodiment, incident radiation 73 having an oblique angle of incidence .theta. illuminates the grating structure 71. The grating structure 71 diffracts radiation 75, 77, 79. Zero-order diffraction 75 is at the same oblique angle .theta. to the substrate as the incident radiation 73. Negative first-order diffraction 77 and positive first-order diffraction 79 are also diffracted by the grating structure 71.

Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83.</td></tr>
<tr><td>86. The method of claim 85, wherein the incident signal has an azimuthal angle of zero degrees.</td><td>Paragraph 74; Figure 6 - Table 1 summarizes the parameters used in the calculations by Gsolver SW.

TABLE 1
Structure parameters used in the simulations
<table>
<tr><th>Parameter</th><th>Data76</th><th>Data0</th></tr>
<tr><td>h1</td><td>850 nm</td><td>850 nm</td></tr>
<tr><td>h2</td><td>850 nm</td><td>850 nm</td></tr>
<tr><td>h3</td><td>600 nm</td><td>600 nm</td></tr>
<tr><td>Pitch (P)</td><td>1000 nm</td><td>2000 nm</td></tr>
<tr><td>CD1</td><td>150 nm</td><td>200 nm</td></tr>
<tr><td>CD2</td><td>300 nm</td><td>600 nm</td></tr>
<tr><td>CD3</td><td>150 nm</td><td>200 nm</td></tr>
<tr><td>Incidence angle (θ)</td><td>76°</td><td>0</td></tr>
<tr><td>Azimuth angle (ϕ)</td><td>0</td><td>0</td></tr>
<tr><td>Wavelength (λ)</td><td>670 nm</td><td>500 nm</td></tr>
</table></td></tr>
<tr><td>87. The method of claim 85, wherein measuring the diffraction signal includes:
measuring the amplitude of the diffraction signal.</td><td>Paragraph 65 - The ellipsometric parameter values were obtained for zero-order diffracted radiation using an incident radiation beam 81 at an angle of 25.degree. to the wafer surface. The ellipsometric parameters, Tan[.psi.] and Cos[.DELTA.], were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers.
Ellipsometric parameters are defined by the equation tan=[rp]/[rs], wherein rp</td></tr>
</table>

	and rs are amplitude reflection coefficients....
88. The method of claim 78 further comprising: generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings, wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.	Paragraph 64 - ... The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
89. The method of claim 88 further comprising: generating a response curve of the correspondence between the different possible misalignments of the first and second sets of gratings and the set of diffraction signals.	Paragraph 64 - ... The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order

	diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
90. The method of claim 88 further comprising: determining the intended asymmetric alignment between the first and second sets of gratings based on the generated set of diffraction signals and range of possible alignments.	Paragraph 8 - The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ...The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information.... The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).

91. The method of claim 88, wherein the set of diffraction signals are generated empirically.	Paragraph 8 - In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - …In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.
92. The method of claim 88, wherein the set of diffraction signals are generated using modeling.	Paragraph 8 - In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - …In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information. Calculations can be performed using known equations or by a software package, such as Lambda SW … or Gsolver SW… The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
93. The method of claim 88, wherein the determining the misalignment between the first and second sets of gratings comprises: comparing the measured diffraction signal to the generated set of diffraction signals; and determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.	Paragraph 8 - In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - …The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or

	critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information.... The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
94. The method of claim 78, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the first and second sets of gratings alternate.	Paragraph 33; Figure 4a - The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. Paragraph 35 - The invention relates to a method of making a target 11. A first periodic structure 13 is placed over a first layer 31 of a device 17. A second periodic structure 15 is placed over a second layer 33 of the device 17. The second periodic structure 15 is overlying or interlaced with the first periodic structure 13. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. The first periodic structure 13 is patterned with the same mask as that for the first layer 31, and the second periodic structure 15 is patterned with the same mask as that for the second layer 33. Thus, the first periodic structure 13 has the same alignment as the first layer 31, and the second periodic structure 15 has the same alignment as the second layer 33. Any misregistration between the first layer 31 and the second layer 33 is reflected in the misregistration between the first periodic structure 13 and the second periodic structure 15. Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment of a target having interlaced gratings. The first periodic structure 13 is etched silicon, and the second periodic target 15 is resist. The first layer 31 of silicon substrate and the second layer 33 of resist are separated by an oxide layer 39.
95. The method of claim 94, wherein the ridges of the first and second sets of gratings include centerlines having a spacing between the centerlines of the ridges of the first and second sets of gratings, and wherein the first and second sets of gratings are symmetrically aligned when the spacing between the centerlines is uniform and asymmetrically aligned when the spacing between the centerlines is non-uniform.	Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15.

	Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. The first periodic structure 13 is patterned with the same mask as that for the first layer 31, and the second periodic structure 15 is patterned with the same mask as that for the second layer 33. Thus, the first periodic structure 13 has the same alignment as the first layer 31, and the second periodic structure 15 has the same alignment as the second layer 33. Any misregistration between the first layer 31 and the second layer 33 is reflected in the misregistration between the first periodic structure 13 and the second periodic structure 15. Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c. The misregistration between the first layer 31 and the second layer 33 is equal to the misregistration .epsilon. between the first periodic structure 13 and the second periodic structure 15. The misregistration ϵ is: $\varepsilon = \frac{b}{2} - \frac{L_3}{2} - c$ Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2.
96.) The method of claim 95, wherein the intended asymmetric alignment includes an offset from symmetrical alignment of the first and	Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a

second sets of gratings.	line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a, the structure is most symmetric at zero overlay misregistration.
97. The method of claim 78, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.	Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
98. The method of claim 97, wherein the ridges of the first and second sets of gratings include centerlines, and wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.	Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
99. The method of claim 98, wherein the intended asymmetric alignment includes an offset from symmetrical alignment of the first and second sets of gratings.	Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a, the structure is most symmetric at zero overlay misregistration.

100. The method of claim 78, wherein forming a periodic grating on the wafer comprises: forming a periodic grating in a first metrology field on the wafer; forming a periodic grating in a second metrology field on the wafer, wherein the first and second metrology fields are separated by a distance on the wafer; obtaining overlay measurements from the first and second metrology fields; and computing an error based on the obtained overlay measurements.	Paragraph 2 - Overlay error measurement requires specially designed marks to be strategically placed at various locations, normally in the scribe line area between dies, on the wafers for each process. The alignment of the two overlay targets from two consecutive processes is measured for a number of locations on the wafer, and the overlay error map across the wafer is analyzed to provide feedback for the alignment control of lithography steppers.
101. A method of obtaining overlay measurements for a semiconductor wafer using a periodic grating, the method comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 6 – A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other. The invention also relates to a method of making overlying or interlaced targets. Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device.
forming a first set of gratings of the periodic grating on the wafer;	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.
forming a second set of gratings of the periodic grating on the wafer,	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.
wherein the first and second sets of gratings are formed using separate masks, and	Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
wherein the second set of gratings are intended to be formed on the wafer with an intended asymmetrical alignment from the first set of gratings when the separate masks are in alignment;	Paragraph 38; Figures 5a, 5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles.

	Paragraph 40, Figures 5a, 5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L.sub.2+L.sub.3 and a line with width L.sub.1. Where c=b-L.sub.3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L.sub.1+L.sub.3 and a line with width L.sub.2. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a, the structure is most symmetric at zero overlay misregistration.
generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,	Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
wherein each of the diffraction signal in the generated set of diffraction signals corresponds to a possible misalignment between the first and second sets of gratings;	Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm).

	Paragraph 77; Figures 21-22 - …FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer,	Paragraph 8 – The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal. The misalignment between the structures is determined from the output signal or the derived signal.
wherein the diffraction signal is measured; and	Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. Paragraph 45 - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83.
determining a misalignment between the first and second sets of gratings based on the measured diffraction signal and the generated set of diffraction signals.	Paragraph 8 – The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - …The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information…. The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
102. The method of claim 101, wherein the determining the misalignment	Paragraph 8 – The misalignment between the structures is determined from the

between the first and second sets of gratings comprises: comparing the measured diffraction signal to the generated set of diffraction signals; and determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.	output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - …The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information.… The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
103. The method of claim 101, wherein the measured diffraction signal is a zero-order diffraction.	Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.

104. The method of claim 101 further comprising:
generating a plurality of sets of diffraction signals at various wavelengths and/or polarizations.

Paragraph 74; Figure 6 - Table 1 summarizes the parameters used in the calculations by Gsolver SW.

TABLE 1

Structure parameters used in the simulations

Parameter	Data76	Data0
h1	850 nm	850 nm
h2	850 nm	850 nm
h3	600 nm	600 nm
Pitch (P)	1000 nm	2000 nm
CD1	150 nm	200 nm
CD2	300 nm	600 nm
CD3	150 nm	200 nm
Incidence angle (θ)	76°	0
Azimuth angle (ϕ)	0	0
Wavelength (λ)	670 nm	500 nm

Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm).

Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).

105. The method of claim 101,
wherein the first and second sets of gratings include a plurality of ridges that alternate with a spacing between the ridges,
wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.

Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15.

Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure

	13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. The first periodic structure 13 is patterned with the same mask as that for the first layer 31, and the second periodic structure 15 is patterned with the same mask as that for the second layer 33. Thus, the first periodic structure 13 has the same alignment as the first layer 31, and the second periodic structure 15 has the same alignment as the second layer 33. Any misregistration between the first layer 31 and the second layer 33 is reflected in the misregistration between the first periodic structure 13 and the second periodic structure 15. Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c. The misregistration between the first layer 31 and the second layer 33 is equal to the misregistration .epsilon. between the first periodic structure 13 and the second periodic structure 15. The misregistration ε is: $\varepsilon = \frac{b}{2} - \frac{L_3}{2} - c$ Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2.
106. The method of claim 101, wherein the first and second sets of gratings include a plurality of ridges with centerlines, wherein the ridges of the second set of gratings are formed on the	Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic

ridges of the first set of gratings, and wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.	structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
107. A method of obtaining overlay measurements for a semiconductor wafer using a periodic grating formed on the wafer, the method comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 6 – A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other. The invention also relates to a method of making overlying or interlaced targets. Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device.
obtaining the wafer, wherein the period grating on the wafer comprises:	Paragraph 2 – Overlay error measurement requires specially designed marks to be strategically placed at various locations, normally in the scribe line area between dies, on the wafers for each process. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer.
a first set of grating that were formed on the wafer using a first mask,	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.

a second set of gratings that were formed on the wafer using a second mask,	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
wherein the first and second sets of gratings were intended to be formed on the wafer with an asymmetric alignment when the first mask and second mask are in alignment;	Paragraph 38; Figures 5a, 5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. Paragraph 40, Figures 5a, 5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L.sub.2+L.sub.3 and a line with width L.sub.1. Where c=b-L.sub.3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L.sub.1+L.sub.3 and a line with width L.sub.2. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a, the structure is most symmetric at zero overlay misregistration.
generating a set of diffraction signals for a plurality of possible misalignments between the first and second sets of gratings;	Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. Paragraph 76; Figures 18-19 - …FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°)…. FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - …FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).

<table>
<tr><td>measuring a diffraction signal of the first and second sets of gratings from the obtained wafer,</td><td>Paragraph 8 – The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal. The misalignment between the structures is determined from the output signal or the derived signal.</td></tr>
<tr><td>wherein the diffraction signal is measured, and</td><td>Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal.

Paragraph 74; Figure 6 - Table 1 summarizes the parameters used in the calculations by Gsolver SW.
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<tr><td>CD3</td><td>150 nm</td><td>200 nm</td></tr>
<tr><td>Incidence angle (Θ)</td><td>76°</td><td>0</td></tr>
<tr><td>Azimuth angle (ϕ)</td><td>0</td><td>0</td></tr>
<tr><td>Wavelength (λ)</td><td>670 nm</td><td>500 nm</td></tr>
</table></td></tr>
<tr><td>wherein the measured diffraction signal is a zero-order diffraction;</td><td>Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures.

Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between</td></tr>
</table>

	the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.
comparing the measured diffraction signal to the generated set of diffraction signals; and	Paragraph 8 – The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - …The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.
determining an amount and direction of misalignment between the first and second sets of gratings on the obtained wafer based on the possible alignment that corresponds to the diffraction signal from the set of diffraction signals that matches the measured diffraction signal.	Paragraph 8 – The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - …The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information…. The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
108. The method of claim 107, wherein the periodic grating on the wafer further comprises: a first periodic grating oriented for obtaining overlay measurements in a first coordinate direction, and	Paragraph 31; Figure 2c - FIGS. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. The second selected width CD2 is less than the first selected width

a second periodic grating oriented for obtaining overlay measurements in a second coordinate direction; and wherein measuring a diffraction signal further comprises: measuring a first diffraction signal from the first periodic grating, and measuring a second diffraction signal from the second periodic grating without rotating the wafer.	CD1. The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
109. The method of claim 108, wherein the measured diffraction signals and the generated diffraction signals have amplitude ratios, and wherein the amplitude ratios of the measured diffraction signals are compared with the amplitude ratios of the generated diffraction signals.	Paragraph 65 - The ellipsometric parameter values were obtained for zero-order diffracted radiation using an incident radiation beam 81 at an angle of 25.degree. to the wafer surface. The ellipsometric parameters, Tan[.psi.] and Cos[.DELTA.], were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. Ellipsometric parameters are defined by the equation tan=[rp]/[rs], wherein rp and rs are amplitude reflection coefficients... Paragraph 45 - ...The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.
110. The method of claim 108, wherein the diffraction signals are measured using an oblique and conical incident signal.	Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83.
111. The method of claim 107, wherein the diffraction signal is measured using a normal incidence angle.	Paragraph 75 - The incidence angle is 76.degree. in the Data 76 configuration, and the incidence angle is 0.degree. (normal) in the Data0 configuration. Paragraph 77; Figures 21-23 - FIGS. 21-23 were derived using the Data0 configuration. FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization

angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm). FIG. 23 shows the MSE variation as a function of overlay misregistration. FIGS. 21 and 22 show the high sensitivity of the intensity of zero-order diffracted radiation to the overlay sign for a configuration using normal incident radiation on interlaced gratings.

112. The method of claim 107, wherein the diffraction signal is measured using an oblique incidence angle with an azimuthal angle.

Paragraph 74; Figure 6 - Table 1 summarizes the parameters used in the calculations by Gsolver SW.

TABLE 1

Structure parameters used in the simulations

Parameter	Data76	Data0
h1	850 nm	850 nm
h2	850 nm	850 nm
h3	600 nm	600 nm
Pitch (P)	1000 nm	2000 nm
CD1	150 nm	200 nm
CD2	300 nm	600 nm
CD3	150 nm	200 nm
Incidence angle (θ)	76°	0
Azimuth angle (ϕ)	0	0
Wavelength (λ)	670 nm	500 nm

113. The method of claim 107, wherein the diffraction signal is measured using an oblique incidence angle with an azimuthal angle of zero degrees.

Paragraph 74; Figure 6 - Table 1 summarizes the parameters used in the calculations by Gsolver SW.

TABLE 1

Structure parameters used in the simulations

Parameter	Data76	Data0
h1	850 nm	850 nm
h2	850 nm	850 nm
h3	600 nm	600 nm
Pitch (P)	1000 nm	2000 nm
CD1	150 nm	200 nm
CD2	300 nm	600 nm
CD3	150 nm	200 nm
Incidence angle (θ)	76°	0
Azimuth angle (ϕ)	0	0
Wavelength (λ)	670 nm	500 nm

114. The method of claim 107,
wherein the first and second sets of gratings include a plurality of ridges that alternate with a spacing between the ridges,

Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the

wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.	second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. The first periodic structure 13 is patterned with the same mask as that for the first layer 31, and the second periodic structure 15 is patterned with the same mask as that for the second layer 33. Thus, the first periodic structure 13 has the same alignment as the first layer 31, and the second periodic structure 15 has the same alignment as the second layer 33. Any misregistration between the first layer 31 and the second layer 33 is reflected in the misregistration between the first periodic structure 13 and the second periodic structure 15. Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c. The misregistration between the first layer 31 and the second layer 33 is equal to the misregistration .epsilon. between the first periodic structure 13 and the second periodic structure 15. The misregistration ε is: $\varepsilon = \frac{b}{2} - \frac{L_3}{2} - c$ Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a

	line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2.
115. The method of claim 107, wherein the first and second sets of gratings include a plurality of ridges with centerlines, wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings, and wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.	Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
116. A system to obtain overlay measurements of a semiconductor wafer, the system comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer.
a periodic grating formed on the wafer comprising:	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.
a first set of gratings formed using a first mask,	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
a second set of gratings formed using a second mask, and	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the

	second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
wherein the first and second sets of gratings are intended to be formed with an asymmetric alignment when the first mask and second mask are in alignment; and	Paragraph 38; Figures 5a, 5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. Paragraph 40, Figures 5a, 5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L.sub.2+L.sub.3 and a line with width L.sub.1. Where c=b-L.sub.3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L.sub.1+L.sub.3 and a line with width L.sub.2. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a, the structure is most symmetric at zero overlay misregistration.
an optical metrology system comprising:	Paragraph 11 - The invention also relates to an apparatus for detecting misalignment of overlying or interlaced periodic structures. The apparatus comprises a source, at least one analyzer, at least one detector, and a signal processor to determine misalignment of overlying or interlaced periodic structures. Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures.
a detector configured to measure a diffraction signal from the first and second sets of gratings, and	Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. Paragraph 11 - The apparatus comprises a source, at least one analyzer, at least one detector, and a signal processor to determine misalignment of overlying or interlaced periodic structures. Paragraph 45; Figure 9a - - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be

	substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85.
a signal processing unit configured to determine a misalignment between the first and second sets of gratings based on the measured diffraction signal.	Paragraph 11 - The apparatus comprises a source, at least one analyzer, at least one detector, and a signal processor to determine misalignment of overlying or interlaced periodic structures. Paragraph 45; Figure 9a - … A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85.
117. The system of claim 116, wherein the signal processing unit is configured to compare the measured diffraction signal to a set of diffraction signals generated for a plurality of possible alignments between the first and second sets of gratings.	Paragraph 45; Figure 9a - … A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information…. The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
118. The system of claim 116, wherein the periodic grating further comprises: a first periodic grating oriented in a first coordinate direction; and	Paragraph 31; Figure 2c - FIGS. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected

a second periodic grating oriented in a second coordinate direction, wherein overlay measurements can be obtained in the first and second coordinate directions using the first and second periodic gratings without rotating the wafer.	width CD2. The second selected width CD2 is less than the first selected width CD1. The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
119. The system of claim 118, wherein the optical metrology system comprises: a source configured to produce an oblique and conical incident signal.	Paragraph 45: Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91.
120. The system of claim 116, wherein the optical metrology system comprises: a source configured to produce a normal incident signal.	Paragraph 48; Figure 9a - The imaging and focusing of the optical system 100 in one embodiment is verified using the vision and pattern recognition system 115. The light source 101 provides a beam for imaging and focusing 87. The beam for imaging and focusing 87 is reflected by beam splitter 113 and focused by lens 111 to the wafer 91. The beam 87 then is reflected back through the lens 111 and beam splitter 113 to the vision and pattern recognition system 115. The vision and pattern recognition system 115 then sends a recognition signal 88 for keeping the wafer in focus for measurement to the signal processor 109. Paragraph 75 - The incidence angle is 76.degree. in the Data 76 configuration, and the incidence angle is 0.degree. (normal) in the Data0 configuration. Paragraph 77; Figures 21-23 - FIGS. 21-23 were derived using the Data0 configuration. FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm,

<table>
<tr><td></td><td>50 nm, and 100 nm). FIG. 23 shows the MSE variation as a function of overlay misregistration. FIGS. 21 and 22 show the high sensitivity of the intensity of zero-order diffracted radiation to the overlay sign for a configuration using normal incident radiation on interlaced gratings.</td></tr>
<tr><td>121. The system of claim 116, wherein the optical metrology system comprises:
a source configured to produce an incident signal having an oblique incidence angle and an azimuthal angle of zero degrees.</td><td>Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103.

Paragraph 74; Figure 6 - Table 1 summarizes the parameters used in the calculations by Gsolver SW.
TABLE 1
Structure parameters used in the simulations
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<tr><td>Pitch (P)</td><td>1000 nm</td><td>2000 nm</td></tr>
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<tr><td>CD3</td><td>150 nm</td><td>200 nm</td></tr>
<tr><td>Incidence angle (θ)</td><td>76°</td><td>0</td></tr>
<tr><td>Azimuth angle (φ)</td><td>0</td><td>0</td></tr>
<tr><td>Wavelength (λ)</td><td>670 nm</td><td>500 nm</td></tr>
</table></td></tr>
<tr><td>122. The system of claim 116, wherein the periodic grating comprises:
a first portion with the first and second sets of gratings having a first alignment; and
a second portion with the first and second sets of gratings having a second alignment.</td><td>Paragraph 31; Figure 2c - FIGS. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. The second selected width CD2 is less than the first selected width CD1. The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is</td></tr>
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	perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
123. The system of claim 122, wherein the detector is configured to measure a first diffraction signal from the first portion of the period grating and a second diffraction signal from the second portion of the periodic grating, and wherein the signal processor is configured to determine the amount and direction of misalignment between the first and second sets of gratings based on the measured first and second diffraction signals.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization or phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason. The polarization of the reflected light is measured by the analyzer in module 105, and the signal processor 109 calculates the ellipsometric parameter values, tan(.psi.) and cos(.DELTA.), from the polarization of the reflected light. The signal processor 109 uses the ellipsometric parameter values to derive polarization and phase information.

	Paragraph 47 - The signal processor 109 determines misalignment from the polarization or phase information, as discussed above.
124. The system of claim 123, wherein the signal processor is configured to determine the alignment of the first and second sets of gratings by comparing the difference between the measured first and second diffraction signals to a set of difference signals generated for a plurality of possible misalignments between the first and second sets of gratings.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.
125. The system of claim 123, wherein the periodic grating further comprises: a third portion having only the first set of gratings; and a fourth portion having the second set of gratings.	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 38; Figures 5a, 5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. Paragraph 40, Figures 5a, 5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L.sub.2+L.sub.3 and a line with width L.sub.1. Where c=b-L.sub.3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L.sub.1+L.sub.3 and a line with width L.sub.2. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a,

	the structure is most symmetric at zero overlay misregistration.
126. The system of claim 125, wherein the optical metrology system comprises: a library of simulated-diffraction signals having a set of theoretical geometry of the first and second sets of gratings; wherein the detector is configured to measure a diffraction signal from the third portion and a diffraction signal from the fourth portion; and wherein the signal processing unit is configured to compare the measured diffraction signal to the simulated-diffraction signals to determine the geometry of the first and second sets of gratings.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information.... The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
127. The system of claim 116, wherein the first and second sets of gratings include a plurality of ridges that alternate with a spacing between the ridges; and wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.	Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. The first periodic structure

	13 is patterned with the same mask as that for the first layer 31, and the second periodic structure 15 is patterned with the same mask as that for the second layer 33. Thus, the first periodic structure 13 has the same alignment as the first layer 31, and the second periodic structure 15 has the same alignment as the second layer 33. Any misregistration between the first layer 31 and the second layer 33 is reflected in the misregistration between the first periodic structure 13 and the second periodic structure 15. Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c. The misregistration between the first layer 31 and the second layer 33 is equal to the misregistration .epsilon. between the first periodic structure 13 and the second periodic structure 15. The misregistration ε is: $\varepsilon = \frac{b}{2} - \frac{L_3}{2} - c$ Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2.
128. The system of claim 116, wherein the first and second sets of gratings include a plurality of ridges with centerlines; wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings; and wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.	Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2....The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right

	edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
129. A method to obtain overlay measurements for a semiconductor wafer, comprising:	Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. Paragraph 79 - Misalignment of overlying or interlaced periodic structures can be determined using the database in a preferred embodiment.
measuring a diffraction signal of a first set of grating and a second set of gratings of a periodic grating formed on the wafer, wherein	Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal.
the first set of gratings were formed using a first mask,	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
the second set of gratings were formed using a second mask, and	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
wherein the first and second sets of gratings were intended to be formed on the wafer with an asymmetric alignment when the first mask and second mask are in alignment;	Paragraph 38; Figures 5a, 5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles.

	Paragraph 40, Figures 5a, 5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L.sub.2+L.sub.3 and a line with width L.sub.1. Where c=b-L.sub.3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L.sub.1+L.sub.3 and a line with width L.sub.2. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a, the structure is most symmetric at zero overlay misregistration.
generating a set of diffraction signals for a plurality of possible misalignments between the first and second sets of gratings;	Paragraph 8 – The invention also relates to a method of detecting misalignment between two layers of a device. The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
determining a misalignment of the first and second sets of gratings formed on the wafer based on the measured diffraction signal and the generated set of diffraction signals; and	Paragraph 8 – The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ...The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The

	misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information.... The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
determining the amount and direction of misalignment between the first and second masks based on the determined misalignment of the first and second sets of gratings formed on the wafer.	Paragraph 8 – The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ...The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information.... The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
130. The method of claim 129, further comprising: obtaining the geometry of the first set of gratings; and obtaining the geometry of the second set of gratings, wherein the generated set of diffraction signals is generated based on the obtained geometry of the first and second sets of gratings.	Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order

	diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83.
131. The method of claim 130, further comprising: measuring diffraction signals of the first set of gratings; measuring diffraction signals of the second set of gratings; and comparing the measured diffraction signals to a library of simulated-diffraction signals having a set of theoretical geometry of the first and second sets of gratings.	Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information.... The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
132. The method of claim 131, wherein the diffraction signals of the first set of gratings are measured from a third portion of the grating having only the first set of gratings, and the diffraction signals of the second set of gratings are measured from a fourth portion of the grating having the second set of gratings.	Paragraph 6 – In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 – The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 38; Figures 5a, 5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. Paragraph 40, Figures 5a, 5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L.sub.2+L.sub.3 and a line with width L.sub.1. Where c=b-L.sub.3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L.sub.1+L.sub.3 and a line with width L.sub.2. Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102

	comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. Paragraph 76 - At an overlay misregistration value of 50 nm, the structure is effectively most symmetric. In contrast, in an overlying target as in FIG. 2a, the structure is most symmetric at zero overlay misregistration.
133. The method of claim 129, further comprising: measuring a first diffraction signal from a first periodic grating; determining the amount and direction of misalignment between the first and second sets of gratings in a first coordinate direction using the first measured diffraction signal; measuring a second diffraction signal from a second periodic grating without rotating the wafer; and determining the amount and direction of misalignment between the first and second sets of gratings in a second coordinate direction using the second measured diffraction signal.	Paragraph 31; Figure 2c - FIGS. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. The second selected width CD2 is less than the first selected width CD1. The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c. Paragraph 37 - ...The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie.

	Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information…. The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
134. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer.
forming a periodic grating on the wafer having: a first set of gratings, wherein the first set of gratings are formed on the wafer using a first mask, and a second set of gratings, wherein the second set of gratings are formed on the wafer using a second mask;	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 27 - This selective exposure is accomplished with an exposure tool and mask 4, or data tape in electron or ion beam lithography (not shown). Paragraph 29; Figures 2a-2b - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a

	second layer 33 of the device.
obtaining zero-order diffracted radiation polarization measurements, of a portion of the periodic grating after forming the first and second sets of gratings; and	Paragraph 9 -Another advantage of this method is the high sensitivity of zero-order and first-order diffracted light to the overlay misregistration between the layers. Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85.
determining any overlay error between the first and second masks used to form the first and second sets of gratings based on the obtained polarization measurements.	Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization and phase information. Paragraph 47 - The signal processor 109 determines misalignment from the polarization or phase information, as discussed above.
135. The method of claim 134, wherein said obtaining obtains zero-order diffracted radiation polarization measurements, with the analyzer polarization at a non-zero angle with respect to the polarizer polarization, of a portion of the periodic grating after forming the first and second sets of gratings.	Paragraph 45 - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing. polarizing optical module 103. The structures diffract zero-order diffracted radiation 83, and a light detection unit

	107 detects the zero-order diffraction radiation 83 collected by the analyzer in module 105 to provide an output signal 85. Paragraph 46 - ...Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
136. The method of claim 134, wherein said obtaining obtains zero-order diffracted radiation polarization measurements, when relative rotational motion is caused between the analyzer polarization and the polarizer polarization, of a portion of the periodic grating after forming the first and second sets of gratings.	Paragraph 45 - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - ...Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
137. The method of claim 134, wherein obtaining zero-order polarization measurements comprises: obtaining a first zero-order polarization measurement; and obtaining a second zero-order polarization measurement, wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order

	diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
138. The method of claim 137, wherein the first and second zero-order polarization measurements are obtained from the same site on the periodic grating.	Paragraph 37 - ...The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105.
139. The method of claim 134, wherein said determining any overlay error comprises: comparing the zero-order polarization measurements to a reference signal.	Paragraph 8 - ...The diffracted radiation from the overlying of interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal. The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ...In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization or phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal.
140. The method of claim 139, wherein the reference signal is generated using modeling.	Paragraph 8 - In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ...In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.

	Paragraph 64 - The invention relates to a method for providing a database to determine misalignment of overlying or interlaced periodic structures. The misalignment of overlying or interlaced periodic structures and structure parameters, such as thickness, refractive index, extinction coefficient, or critical dimension, are provided to calculate data related to radiation diffracted by the structures in response to a beam of radiation. The data can include intensity, polarization angle, or phase information. Calculations can be performed using known equations or by a software package, such as Lambda SW … or Gsolver SW… The data is used to construct a database correlating the misalignment and the data. The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database.
141. The method of claim 134 further comprising: obtaining a set of first zero-order polarization measurements for a range of possible misalignments between the first and second masks; and obtaining a set of second zero-order polarization measurements for a range of possible misalignments between the first and second masks.	Paragraph 64 - … The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - …FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°)…. FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - …FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
142. The method of claim 141 further comprising: generating a first response curve based on the set of first zero-order polarization measurements, wherein the first response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of first zero-order polarization measurements; and generating a second response curve based on the set of second zero-order polarization measurements, wherein the second response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of	Paragraph 64 - … The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters using an overlying target of FIG. 2a with the optical system of FIG. 9a.

second zero-order polarization measurements.	Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
143. The method of claim 134, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - ...FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. ...The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$ Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14.

	Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
144. The method of claim 134, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - ...FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. ...The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$ Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14.

	Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
145. The method of claim 134, wherein the zero-order polarization measurements are obtained using an optical metrology system.	Paragraph 65; Figures 12a-12b - FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a.
146. The method of claim 145, wherein the optical metrology system includes a reflectometer or an ellipsometer.	Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
147. The method of claim 146, wherein the ellipsometer includes: a	Paragraph 45; Figure 9a - Optical systems for determining misalignment of

polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain a second zero-order polarization measurement.	overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
148. The method of claim 134, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the first and second sets of gratings alternate.	Paragraph 33; Figure 4a - The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. Paragraph 35 - The invention relates to a method of making a target 11. A first periodic structure 13 is placed over a first layer 31 of a device 17. A second periodic structure 15 is placed over a second layer 33 of the device 17. The second periodic structure 15 is overlying or interlaced with the first periodic structure 13. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. The first periodic structure 13 is patterned with the same mask as that for the first layer 31, and the second periodic structure 15 is patterned with the same mask as that for the second layer 33. Thus, the first periodic structure 13 has the same alignment as the first layer 31, and the second periodic structure 15 has the same alignment as

	the second layer 33. Any misregistration between the first layer 31 and the second layer 33 is reflected in the misregistration between the first periodic structure 13 and the second periodic structure 15. Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment of a target having interlaced gratings. The first periodic structure 13 is etched silicon, and the second periodic target 15 is resist. The first layer 31 of silicon substrate and the second layer 33 of resist are separated by an oxide layer 39.
149. The method of claim 148, wherein the ridges of the first and second sets of grating having a spacing between them; and wherein the first and second sets of gratings are formed with the spacing between them uniform when the first and second masks are aligned without an overlay error.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c. The misregistration between the first layer 31 and the second layer 33 is equal to the misregistration .epsilon. between the first periodic structure 13 and the second periodic structure 15. The misregistration ϵ is: $\varepsilon = \frac{b}{2} - \frac{L_3}{2} - c$ Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2.
150. The method of claim 134, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.	Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right

	edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
151. The method of claim 150, wherein the ridges of the first and second sets of gratings include centerlines, and wherein the first and second sets of gratings are formed with the centerlines of the ridges aligned when the first and second masks are aligned without an overlay error.	Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
152. The method of claim 134, wherein the periodic grating is formed from isotropic materials.	Paragraph 34; Figure 4b - In another embodiment, FIG. 4b illustrates a first periodic structure 13 of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
153. The method of claim 134, wherein the zero-order polarization measurements are obtained using an oblique incident signal.	Paragraph 44; Figure 8 - The invention relates to a method to determine misalignment using diffracted light. FIG. 8 is a schematic view showing the diffraction of light from a grating structure 71. In one embodiment, incident radiation 73 having an oblique angle of incidence .theta. illuminates the grating structure 71. The grating structure 71 diffracts radiation 75, 77, 79. Zero-order diffraction 75 is at the same oblique angle .theta. to the substrate as the incident radiation 73. Negative first-order diffraction 77 and positive first-order diffraction 79 are also diffracted by the grating structure 71. Paragraph 45; Figure 9a - Optical systems for determining misalignment of

	overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83.
154. The method of claim 134, wherein the first and second sets of gratings are formed from different materials.	Paragraph 27 - As shown in FIGS. 1a-1h, a device 17 is generally formed in a basic series of steps for each layer. ...Alternatively, in another embodiment, another material 8 can be deposited in the spaces 7, as shown in FIG. 1e, of the etched layer 2, as shown in FIG. 1g, ... This basic series of steps is repeated for each layer until the desired device is formed. Paragraph 33; Figure 4a - ...In one embodiment, FIG. 4a illustrates a first periodic structure 13 of oxide having a trapezoidal shape on a first layer 31 of silicon substrate and a second periodic structure 15 of resist with a second layer 33 of resist. Paragraph 34; Figure 4b - In another embodiment, FIG. 4b illustrates a first periodic structure 13 of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37. Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment of a target having interlaced gratings. The first periodic structure 13 is etched silicon, and the second periodic target 15 is resist. The first layer 31 of silicon substrate and the second layer 33 of resist are separated by an oxide layer 39.
155. The method of claim 134, wherein the first and second sets of gratings are formed from different materials and have different heights.	Paragraph 6 - ...The layers or periodic structures may be at the same or different heights. Paragraph 33; Figure 4a - ...In one embodiment, FIG. 4a illustrates a first periodic structure 13 of oxide having a trapezoidal shape on a first layer 31 of silicon substrate and a second periodic structure 15 of resist with a second layer 33 of resist. Paragraph 34; Figure 4b - In another embodiment, FIG. 4b illustrates a first periodic structure 13 of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37. Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment of a target having interlaced gratings. The first periodic structure 13 is etched silicon, and the second periodic target 15 is resist. The first layer 31 of silicon substrate and

<table>
<tr><td></td><td>the second layer 33 of resist are separated by an oxide layer 39.

Paragraph 74; Figure 6 - Table 1 summarizes the parameters used in the calculations by Gsolver SW.

TABLE 1
Structure parameters used in the simulations
<table>
<tr><th>Parameter</th><th>Data76</th><th>Data0</th></tr>
<tr><td>h1</td><td>850 nm</td><td>850 nm</td></tr>
<tr><td>h2</td><td>850 nm</td><td>850 nm</td></tr>
<tr><td>h3</td><td>600 nm</td><td>600 nm</td></tr>
<tr><td>Pitch (P)</td><td>1000 nm</td><td>2000 nm</td></tr>
<tr><td>CD1</td><td>150 nm</td><td>200 nm</td></tr>
<tr><td>CD2</td><td>300 nm</td><td>600 nm</td></tr>
<tr><td>CD3</td><td>150 nm</td><td>200 nm</td></tr>
<tr><td>Incidence angle (θ)</td><td>76°</td><td>0</td></tr>
<tr><td>Azimuth angle (φ)</td><td>0</td><td>0</td></tr>
<tr><td>Wavelength (λ)</td><td>670 nm</td><td>500 nm</td></tr>
</table></td></tr>
<tr><td>156. The method of claim 134, wherein the first and second sets of gratings have different linewidths.</td><td>Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53.</td></tr>
<tr><td>157. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:</td><td>Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures.

Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer.</td></tr>
<tr><td>forming a periodic grating on the wafer having: a first set of periodic gratings, and a second set of periodic gratings, wherein the first and second sets of periodic gratings are formed using separate masks;</td><td>Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.

Paragraph 27 - This selective exposure is accomplished with an exposure tool and mask 4, or data tape in electron or ion beam lithography (not shown).</td></tr>
</table>

	Paragraph 29; Figures 2a-2b - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
obtaining zero-order polarization measurements from the periodic grating after forming the first and second sets of gratings, wherein the zero-order polarization measurements are obtained using an oblique incident angle; and	Paragraph 9 -Another advantage of this method is the high sensitivity of zero-order and first-order diffracted light to the overlay misregistration between the layers. Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 44; Figure 8 - The invention relates to a method to determine misalignment using diffracted light. FIG. 8 is a schematic view showing the diffraction of light from a grating structure 71. In one embodiment, incident radiation 73 having an oblique angle of incidence .theta. illuminates the grating structure 71. The grating structure 71 diffracts radiation 75, 77, 79. Zero-order diffraction 75 is at the same oblique angle .theta. to the substrate as the incident radiation 73. Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83.
determining any overlay error associated with the formation of the first and second sets of gratings based on the obtained zero-order polarization measurements.	Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization and phase information. Paragraph 47 - The signal processor 109 determines misalignment from the

	polarization or phase information, as discussed above.
158. The method of claim 157, wherein obtaining zero-order polarization measurements comprises: obtaining a first zero-order polarization measurement; and obtaining a second zero-order polarization measurement, wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
159. The method of claim 157, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - ...FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. ...The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$

	Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
160. The method of claim 157, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - ...FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. ...The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$

	Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
161. The method of claim 157, wherein the first and second zero-order polarization measurements are obtained from a single site on the periodic grating.	Paragraph 37 - ...The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105.
162. The method of claim 157 further comprising: obtaining a set of first zero-order polarization measurements for a range of possible misalignments between the first and second gratings; and obtaining a set of second zero-order polarization measurements for a range of possible misalignments between the first and second gratings.	Paragraph 64 - ... The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a.

	Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
163. The method of claim 162 further comprising: generating a first response curve based on the set of first zero-order polarization measurements; and generating a second response curve based on the set of second zero-order polarization measurements, wherein the first and second response curves characterize a relationship between the different possible misalignments of the first and second gratings and the zero-order polarization measurements.	Paragraph 64 - ... The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
164. The method of claim 157, wherein the zero-order polarization measurements are obtained using an ellipsometer having: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order polarization measurement, and wherein the polarizer	Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation

and the analyzer are set to a second angular setting to obtain a second zero-order polarization measurement.	83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
165. The method of claim 157, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the first and second sets of gratings alternate.	Paragraph 33; Figure 4a - The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. Paragraph 35 - The invention relates to a method of making a target 11. A first periodic structure 13 is placed over a first layer 31 of a device 17. A second periodic structure 15 is placed over a second layer 33 of the device 17. The second periodic structure 15 is overlying or interlaced with the first periodic structure 13. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. The first periodic structure 13 is patterned with the same mask as that for the first layer 31, and the second periodic structure 15 is patterned with the same mask as that for the second layer 33. Thus, the first periodic structure 13 has the same alignment as the first layer 31, and the second periodic structure 15 has the same alignment as the second layer 33. Any misregistration between the first layer 31 and the second layer 33 is reflected in the misregistration between the first periodic structure 13 and the second periodic structure 15.

	Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment of a target having interlaced gratings. The first periodic structure 13 is etched silicon, and the second periodic target 15 is resist. The first layer 31 of silicon substrate and the second layer 33 of resist are separated by an oxide layer 39.
166. The method of claim 165, wherein the ridges of the first and second sets of grating have a spacing between them; and wherein the first and second sets of gratings are formed with the spacing between them nonuniform when an overlay error exists.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c. The misregistration between the first layer 31 and the second layer 33 is equal to the misregistration .epsilon. between the first periodic structure 13 and the second periodic structure 15. The misregistration ϵ is: $$\varepsilon = \frac{b}{2} - \frac{L_3}{2} - c$$ Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2.
167. The method of claim 157, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.	Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other

	words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
168. The method of claim 167, wherein the ridges of the first and second sets of gratings include centerlines, and wherein the first and second sets of gratings are formed with the centerlines of the ridges misaligned when an overlay error exists.	Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
169. The method of claim 157, wherein the periodic grating is formed from isotropic materials.	Paragraph 34; Figure 4b - In another embodiment, FIG. 4b illustrates a first periodic structure 13 of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
170. A method of obtaining overlay measurements for a semiconductor wafer having a periodic grating with a first set of gratings and a second set of gratings, the method comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.

	Paragraph 29; Figures 2a-2b - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
obtaining a first zero-order polarization measurement from the periodic grating;	Paragraph 9 -Another advantage of this method is the high sensitivity of zero-order and first-order diffracted light to the overlay misregistration between the layers. Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85.
obtaining a second zero-order polarization measurement from the periodic grating, wherein the first and second zero-order polarization measurements are obtained using an oblique incident angle, wherein the first and second zero-order polarization measurements are obtained from a single site on the periodic grating, and wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement; and	Paragraph 37 - ...The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie. Paragraph 44; - The invention relates to a method to determine misalignment using diffracted light. FIG. 8 is a schematic view showing the diffraction of light from a grating structure 71. In one embodiment, incident radiation 73 having an oblique angle of incidence .theta. illuminates the grating structure 71. The grating structure 71 diffracts radiation 75, 77, 79. Zero-order diffraction 75 is at the same oblique angle .theta. to the substrate as the incident radiation 73. Negative first-order diffraction 77 and positive first-order diffraction 79 are also diffracted by the grating structure 71. Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information.

	In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
determining any overlay error associated with the formation of the first and second sets of gratings based on the obtained first and second zero-order polarization measurements.	Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization or phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal.

	Paragraph 47 - The signal processor 109 determines misalignment from the polarization or phase information, as discussed above.
171. The method of claim 170, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - …FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. …The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$ Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14. Paragraph 76; Figures 18-19 - …FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°)…. FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - …FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the

	incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
172. The method of claim 170, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - …FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. …The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$ Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14. Paragraph 76; Figures 18-19 - …FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).… FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - …FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the

	incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
173. The method of claim 170, wherein the periodic grating is formed from isotropic materials.	Paragraph 34 - In another embodiment, FIG. 4b illustrates a first periodic structure 13 of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
174. The method of claim 170 further comprising: obtaining a set of first zero-order polarization measurements for a range of possible misalignments between the first and second gratings; and obtaining a set of second zero-order polarization measurements for a range of possible misalignments between the first and second gratings.	Paragraph 64 - … The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - …FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°)…. FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - …FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
175. The method of claim 170 further comprising: generating a first response curve based on the set of first zero-order polarization measurements; and generating a second response curve based on the set of second zero-order polarization measurements, wherein the first and second response curves characterize a relationship between the different possible misalignments of the first and second gratings and the zero-order polarization measurements.	Paragraph 64 - … The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - …FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°)…. FIG. 19 shows the dependence of the

	intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
176. The method of claim 170, wherein the first and second zero-order polarization measurements are obtained using an ellipsometer having: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain the first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain the second zero-order polarization measurement.	Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
177. A system to obtain overlay measurements of a semiconductor wafer, the system comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between

	successive layers on a semiconductor wafer.
a periodic grating formed on the wafer comprising: a first set of gratings formed using a first mask, a second set of gratings formed using a second mask; and	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 27 - This selective exposure is accomplished with an exposure tool and mask 4, or data tape in electron or ion beam lithography (not shown). Paragraph 29; Figures 2a-2b - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
an optical metrology system configured to: obtain zero-order polarization measurements from the periodic grating after the first and second sets of gratings are formed on the wafer, and determine any overlay error between the first and second masks used to form the first and second sets of gratings based on the obtained zero-order polarization measurements.	Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization and phase information. Paragraph 47 - The signal processor 109 determines misalignment from the polarization or phase information, as discussed above.
178. The system of claim 177, wherein the optical metrology system is configured to: obtain a first zero-order polarization measurement; and obtain a second zero-order polarization measurement, wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order

	diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
179. The system of claim 177, wherein the first and second zero-order polarization measurements are obtained from the same site on the periodic grating.	Paragraph 37 - ...The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105.
180. The system of claim 177, wherein the optical metrology system is configured to: compare the zero-order polarization measurements to a reference signal.	Paragraph 8 - ...The diffracted radiation from the overlying of interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal. The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ...In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization or phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal.
181. The system of claim 177, wherein the first zero-order polarization	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric

measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.	parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - …FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. …The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$ Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14. Paragraph 76; Figures 18-19 - …FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°)…. FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - …FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
182. The system of claim 177, wherein the first zero-order polarization	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric

measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.	parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - ...FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. ...The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$ Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
183. The system of claim 177, wherein the optical metrology system	Paragraph 45; Figure 9a - Optical systems for determining misalignment of

includes a reflectometer or an ellipsometer.	overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
184. The system of claim 183, wherein the ellipsometer includes: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain a second zero-order polarization measurement.	Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric

	parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
185. The system of claim 177, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the first and second sets of gratings alternate.	Paragraph 33. Figure 4a - The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. Paragraph 35 - The invention relates to a method of making a target 11. A first periodic structure 13 is placed over a first layer 31 of a device 17. A second periodic structure 15 is placed over a second layer 33 of the device 17. The second periodic structure 15 is overlying or interlaced with the first periodic structure 13. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths or duty cycles. The first periodic structure 13 is patterned with the same mask as that for the first layer 31, and the second periodic structure 15 is patterned with the same mask as that for the second layer 33. Thus, the first periodic structure 13 has the same alignment as the first layer 31, and the second periodic structure 15 has the same alignment as the second layer 33. Any misregistration between the first layer 31 and the second layer 33 is reflected in the misregistration between the first periodic structure 13 and the second periodic structure 15. Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment of a target having interlaced gratings. The first periodic structure 13 is etched silicon, and the second periodic target 15 is resist. The first layer 31 of silicon substrate and the second layer 33 of resist are separated by an oxide layer 39.
186. The system of claim 185, wherein the ridges of the first and second sets of grating have a spacing between them; and wherein the first and second sets of gratings are formed with the spacing between them uniform when the first and second masks are aligned without an overlay error.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the

	adjacent left edge of the second interlaced grating 53 is represented by c. The misregistration between the first layer 31 and the second layer 33 is equal to the misregistration .epsilon. between the first periodic structure 13 and the second periodic structure 15. The misregistration ϵ is: $$\varepsilon = \frac{b}{2} - \frac{L_3}{2} - c$$ Paragraph 40; Figures 5a-5b - Where c=0, the resulting periodic structure has the most asymmetric unit cell composed of a line with width of L2+L3 and a line with width L1. Where c=b-L3, the resulting periodic structure has the most symmetric unit cell composed of a line with width L1+L3 and a line with width L2.
187. The system of claim 177, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.	Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
188. The system of claim 187, wherein the ridges of the first and second sets of gratings include centerlines, and wherein the first and second sets of gratings are formed with the centerlines of the ridges aligned when the first and second masks are aligned without an overlay error.	Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figures 2a-2b - FIG. 2b and 2c are top views of target 11. In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a

	first selected width CD1, and the second periodic structure 15 has a second selected width CD2. ...The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d1=d2. In this embodiment, the misregistration is indicated by d2-d1.
189. The system of claim 177, wherein the periodic grating is formed from isotropic materials.	Paragraph 34; Figure 4b - In another embodiment, FIG. 4b illustrates a first periodic structure 13 of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
190. The system of claim 177, wherein the optical metrology system obtains the zero-order polarization measurements using an oblique incident signal.	Paragraph 44; Figure 8 - The invention relates to a method to determine misalignment using diffracted light. FIG. 8 is a schematic view showing the diffraction of light from a grating structure 71. In one embodiment, incident radiation 73 having an oblique angle of incidence .theta. illuminates the grating structure 71. The grating structure 71 diffracts radiation 75, 77, 79. Zero-order diffraction 75 is at the same oblique angle .theta. to the substrate as the incident radiation 73. Negative first-order diffraction 77 and positive first-order diffraction 79 are also diffracted by the grating structure 71. Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83.
191. A system to obtain overlay measurements of a semiconductor wafer having a periodic grating with a first set of gratings and a second set of gratings, the system comprising: an optical metrology system configured to:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles.

	Paragraph 29; Figures 2a-2b - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
obtain a first zero-order polarization measurement from a site on the periodic grating;	Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105.
obtain a second zero-order polarization measurement from the same site on the periodic grating as the first zero-order polarization measurement; and	Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 37 - …The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie. Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer

	in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105.
determine any overlay error associated with the formation of the first and second sets of gratings based on the obtained first and second zero-order polarization measurements.	Paragraph 45 - …A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization and phase information. Paragraph 47 - The signal processor 109 determines misalignment from the polarization or phase information, as discussed above.
192. The system of claim 191, wherein the optical metrology system includes: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain the first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain the second zero-order polarization measurement.	Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
193. The system of claim 191, wherein the optical metrology system is configured to: compare the first zero-order polarization measurement and the second zero-order polarization measurement to a reference signal to determine	Paragraph 8 - …The diffracted radiation from the overlying of interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal. The misalignment between the

whether an overlay error exists.	structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ...In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization and phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal.
194. The system of claim 191, wherein the periodic grating is formed from isotropic materials.	Paragraph 34; Figure 4b - In another embodiment, FIG. 4b illustrates a first periodic structure 13 of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
195. The system of claim 191, wherein the optical metrology system obtains the zero-order polarization measurements using an oblique incident signal.	Paragraph 44; Figure 8 - The invention relates to a method to determine misalignment using diffracted light. FIG. 8 is a schematic view showing the diffraction of light from a grating structure 71. In one embodiment, incident radiation 73 having an oblique angle of incidence .theta. illuminates the grating structure 71. The grating structure 71 diffracts radiation 75, 77, 79. Zero-order diffraction 75 is at the same oblique angle .theta. to the substrate as the incident radiation 73. Negative first-order diffraction 77 and positive first-order diffraction 79 are also diffracted by the grating structure 71. Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83.
196. The system of claim 191, wherein the second zero-order polarization measurement is obtained with the analyzer polarization different from the polarizer polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization

	angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
197. A device containing computer executable instructions for causing a computer to obtain overlay measurements for a semiconductor wafer, comprising instructions for:	Paragraph 11 - The invention also relates to an apparatus for detecting misalignment of overlying or interlaced periodic structures. The apparatus comprises a source, at least one analyzer, at least one detector, and a signal process to determine misalignment of overlying or interlaced periodic structures. Paragraph 45; Figure 9a - Optical systems for determining misalignment of overlying or interlaced periodic structures are illustrated in FIGS. 9a, 10a, and 11a. FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below.
obtaining zero-order polarization measurements from a periodic grating formed on the wafer, wherein a first set of gratings of the periodic grating are formed on the wafer using a first mask, and wherein a second set of gratings of the periodic grating are formed on the wafer using a second mask; and	Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures. Paragraph 27 - This selective exposure is accomplished with an exposure tool

	and mask 4, or data tape in electron or ion beam lithography (not shown). Paragraph 29; Figures 2a-2b - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85.
determining any overlay error between the first mask and the second mask used to form the first and second sets of gratings based on the obtained zero-order polarization measurements.	Paragraph 45 - The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization and phase information. Paragraph 47 - The signal processor 109 determines misalignment from the polarization or phase information, as discussed above.
198. The device of claim 197, wherein obtaining zero-order polarization measurements comprises: obtaining a first zero-order polarization measurement; and obtaining a second zero-order polarization measurement, wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason. Paragraph 64 - … The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS.

	12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
199. The device of claim 197, wherein determining any overlay error comprises: comparing the zero-order polarization measurements to a reference signal.	Paragraph 8 - ...The diffracted radiation from the overlying of interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal. The misalignment between the structures is determined from the output signal or the derived signal. In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 45 - ... In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization and phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal.
200. The device of claim 197, said instructions further comprising: obtaining a set of first zero-order polarization measurements for a range of possible misalignments between the first and second masks; and obtaining a set of second zero-order polarization measurements for a range of possible misalignments between the first and second masks.	Paragraph 64 - ... The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG.

	9a. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
201. The device of claim 200 said instructions further comprising: generating a first response curve based on the set of first zero-order polarization measurements, wherein the first response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of first zero-order polarization measurements; and generating a second response curve based on the set of second zero-order polarization measurements, wherein the second response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of second zero-order polarization measurements.	Paragraph 64 - ... The overlay misregistration of a target can then be determined by comparing the output signal 85 with the database. Paragraph 65; Figures 12a-12b - FIGS. 12-24 were generated through computer simulations using either the Lambda SW or the Gsolver SW. FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
202. The device of claim 197, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer

	in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - ...FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. ...The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$ Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
203. The device of claim 197, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer

	in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Paragraph 65 - ...FIGS. 12a and 12b are graphical plots illustrating the ellipsometric parameters obtained using an overlying target of FIG. 2a with the optical system of FIG. 9a. ...The ellipsometric parameters, Tan ψ and Cos Δ, were plotted as a function of the wavelengths in the spectral range 230 to 400 nanometers. The ellipsometric parameters are defined as: $\tan\psi = [r_p]/[r_s]$ Paragraph 66 - where r_p and r_s are the amplitude reflection coefficients for the p(TM) and s(TE) polarizations, and $\Delta=\Phi_p-\Phi_s$ Paragraph 67 - where Φ_p and Φ_s are the phases for the p(TM) and s(TE) polarizations. Results were obtained for different values of overlay misregistration d.sub.2-d.sub.1 varying from -15 nanometers to 15 nanometers in steps of 5 nanometers. The variations for tan[.psi.] and cos[.DELTA.] show sensitivity to the misregistration in the nanometer scale. To get more accurate results, first-order diffracted radiation is detected using normal incident radiation, as in FIGS. 13-14. Paragraph 76; Figures 18-19 - ...FIG. 18 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0° to 90° in steps of 15°).... FIG. 19 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-50 nm, -15 nm, 0 nm, 20 nm, 40 nm, 60 nm, 80 nm, 100 nm, and 130 nm). Paragraph 77; Figures 21-22 - ...FIG. 21 shows the intensity of the zero-order diffracted radiation versus the overlay misregistration at different polarization angles (0.degree., 40.degree., 65.degree., and 90.degree.). FIG. 22 shows the dependence of the intensity of the zero-order diffracted radiation on the incident polarization angle at different overlay misregistrations (-140 nm, -100 nm, -50 nm, 0 nm, 50 nm, and 100 nm).
204. The device of claim 197, wherein the first and second zero-order polarization measurements are obtained from a single site on the periodic grating.	Paragraph 37 - ...The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a

	separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105.
205. A method of obtaining overlay measurements, the method comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets… Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 8 - The invention also relates to a method of detecting misalignment between two layers of a device.
forming a first grating test pattern using a first layer mask;	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
forming a second grating test pattern using a second layer mask,	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
wherein the first and second grating test patterns have the same periodicity;	Paragraph 31; Figure 2a - In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2… The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the

	right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1.
measuring the first and second grating test patterns using an optical metrology equipment; and	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 8 - The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal... In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 11- The invention also relates to an apparatus for detecting misalignment of overlying or interlaced periodic structures. The apparatus comprises a source, at least one analyzer, at least one detector, and a signal processor to determine misalignment of overlying or interlaced periodic structures. Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures.
measuring the alignment of the second layer mask to the first layer mask based on the measurement of the first and second grating test patterns.	Paragraph 8 - The misalignment between the structures is determined from the output signal or the derived signal. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33.

	Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15.
206. The method of claim 205, wherein grating lines of the second grating test pattern are formed on top of grating lines of the first grating test pattern.	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. The invention also relates to a method of making overlying or interlaced targets. Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figures 2a-2b - In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13.
207. The method of claim 206, wherein a first distance measures a gap from a left edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed on top of the first grating line of the first grating test pattern.	Paragraph 31; Figures 2a-2b - The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1...
208. The method of claim 207, wherein a second distance measures a gap from the right edge of the first grating line of the first grating test pattern to the right edge of the first grating line of the second grating test pattern.	Paragraph 31; Figures 2a-2b - ...and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2.
209. The method of claim 206, further comprising: forming one or more material layers between the first grating test pattern and the second grating test pattern.	Paragraph 33; Figure 4a - FIGS. 4a and 4b show alternative embodiments... An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. The invention also encompasses embodiments such as the line on line configuration. where the lines in the second periodic structure 15 are placed on top of and aligned with the lines in the first periodic structure 13, as shown by the dotted lines in FIG. 4a. Paragraph 34; Figure 4b - In another embodiment, FIG 4b illustrates a first periodic structure of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31

	and the second layer 33 are separated by an aluminum blanket 37.
210. The method of claim 205, wherein grating lines of the second grating test pattern are interlaced with grating lines of the first grating test pattern.	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other… The invention also relates to a method of making overlying or interlaced targets. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths, or duty cycles.
211. The method of claim 210, wherein a first distance measures a gap from a right edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
212. The method of claim 211, wherein a second distance measures a gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern, wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
213. The method of claim 210, further comprising: forming one or more material layers between the first grating test pattern and the second grating test pattern.	Paragraph 33; Figure 4a - FIGS. 4a and 4b show alternative embodiments… An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13 Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment… The first layer 31 of silicon substrate and the second layer 33 of resist are separated by

	an oxide layer 39.
214. The method of claim 205, wherein the first and second grating test patterns include: a first grating having grating lines in a first orientation; and a second grating having grating lines in a second orientation perpendicular to the first orientation, wherein the second grating is adjacent to the first grating.	Paragraph 31; Figure 2c - To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c. Paragraph 36; Figure 2c - In one embodiment, another target 12 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
215. The method of claim 214, wherein the first and second grating test patterns include: a third grating having grating lines in a third orientation, wherein the third orientation is 45 degrees relative to the first orientation; and a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation, wherein the fourth grating is adjacent to the third grating and the second grating.	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device… In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 36 - A third periodic structure 14 is placed over the first layer 31, and a fourth periodic structure 14 is placed over the second layer 33. The third periodic structure 14 is substantially perpendicular to the first periodic structure 13, and the fourth periodic structure 16 is substantially perpendicular to the second periodic structure 15.
216. The method of claim 215, wherein the first, second, third, and fourth gratings are quadrants in a four-quadrant test pattern formed on a semiconductor wafer.	Paragraph 2 - Overlay error measurement requires specially designed marks to be strategically placed at various locations, normally in the scribe line area between dies, on the wafers for each process. The alignment of the two overlay targets from two consecutive processes is measured for a number of locations on the wafer, and the overlay error map across the wafer is analyzed to provide feedback for the alignment control of lithography steppers.
217. The method of claim 216, wherein measuring the first and second grating test patterns comprises: measuring the first, second, third, and fourth gratings without rotating or reloading the semiconductor wafer.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an

	output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization or phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
218. The method of claim 217, wherein measuring the alignment of the second layer mask to the first layer mask comprises: measuring the alignment in the first, second, third, and fourth orientations based on the measurement of the first, second, third, and fourth gratings.	Paragraph 2 - Overlay error measurement requires specially designed marks to be strategically placed at various locations, normally in the scribe line area between dies, on the wafers for each process. The alignment of the two overlay targets from two consecutive processes is measured for a number of locations on the wafer, and the overlay error map across the wafer is analyzed to provide feedback for the alignment control of lithography steppers. Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15.
219. The method of claim 205, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order

	diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. Paragraph 46; Figure 9a - In one embodiment, optical system 100 provides ellipsometric parameter values...The polarization of the reflected light is measured by the analyzer in module 105, and the signal processor 109 calculates the ellipsometric parameter values... The signal processor 109 uses the ellipsometric parameter values to derive polarization and phase information. Paragraph 49; Figure 10a - Analyzers 121, 119 collect positive first-order diffracted radiation 95 and negative first-order diffracted radiation 93, respectively. Light detection units 125, 123 detect the positive first-order diffracted radiation 95 and the negative first-order diffracted radiation 93, respectively, collected by analyzers 121, 119, respectively, to provide output signals 85. A signal processor 109 determines any misalignment between the structures from the output signals 85, preferably by comparing the output signals 85 to a reference signal. In one embodiment, the signal processor 109 calculates a derived signal from the output signals 85. The derived signal is a differential signal between the positive first-order diffracted radiation 95 and the negative first-order diffracted radiation 93. The differential signal can indicate a differential intensity, a differential polarization angle, or a differential phase. Paragraph 50 - To determine differential phase, optical system 110 in one embodiment uses an ellipsometric arrangement comprising ... Paragraph 52; Figure 10a - To determine differential intensity, in one embodiment, the analyzers 119, 121 are positioned without relative rotation at the polarization angle of the first-order diffracted radiation .93, 95. Preferably, at the polarization angle where the intensity of the diffracted radiation is a maximum, the intensity of the positive first-order diffracted radiation 95 and the intensity of the negative first-order diffracted intensity 93 is detected by the detectors 125, 123. Differential intensity is calculated by subtracting the intensity for the negative first-order diffracted radiation 93 from the intensity for the positive first-order diffracted radiation 95.
220. A method of obtaining overlay measurements, the method comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a

forming a first grating test pattern using a first layer mask; forming a second grating test pattern using a second layer mask, wherein the first and second grating test patterns have the same periodicity, and wherein the first and second grating test patterns have: a first grating having grating lines in a first orientation, and a second grating having grating lines in a second orientation perpendicular to the first orientation; measuring the first and second grating patterns including the first and second gratings using an optical metrology equipment; and measuring the alignment of the second layer mask to the first layer mask in the first and second orientations based on the measurement of the first and second grating patterns including the first and second gratings.	metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figure 2c - In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
221. The method of claim 220, wherein a first distance measures a gap from a left edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the first grating test pattern is formed on top of the first grating line of the second grating test pattern, and wherein a second distance measures a gap from the right edge of the first grating line of the first grating test pattern to the right edge of the first grating line of the second grating test pattern.	Paragraph 31; Figures 2a-2b - The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2... In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the

	XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
222. The method of claim 220, wherein a first distance measures a gap from a right edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern, wherein a second distance measures a gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern, and wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
223. The method of claim 220, wherein the first and second gratings are formed on a semiconductor wafer, and wherein the first and second gratings are measured using the optical metrology equipment without reloading the semiconductor wafer.	Paragraph 37 - ...The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie. Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization or phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal.

	Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
224. The method of claim 220, wherein the first and second grating test patterns include: a third grating having grating lines in a third orientation, wherein the third orientation is 45 degrees relative to the first orientation; and a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation.	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device… In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 36 - A third periodic structure 14 is placed over the first layer 31, and a fourth periodic structure 14 is placed over the second layer 33. The third periodic structure 14 is substantially perpendicular to the first periodic structure 13, and the fourth periodic structure 16 is substantially perpendicular to the second periodic structure 15.
225. A structure formed on a semiconductor wafer for obtaining overlay measurements, the structure comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets… Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other.
a first grating test pattern formed on the semiconductor wafer using a first layer mask; and	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the

	second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
a second grating test pattern formed on the semiconductor wafer using a second layer mask,	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
wherein the first and second grating test patterns have the same periodicity,	Paragraph 31; Figures 2a-2b - In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2… The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1.
wherein the first and second grating test patterns are measured using an optical metrology equipment, and	Paragraph 8 - The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal… In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 11- The invention also relates to an apparatus for detecting misalignment of overlying or interlaced periodic structures. The apparatus comprises a source, at least one analyzer, at least one detector, and a signal processor to determine misalignment of overlying or interlaced periodic structures. Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures.

wherein the alignment of the second layer mask to the first layer mask is measured based on the measurement of the first and second grating test patterns.	Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15.
226. The structure of claim 225, wherein grating lines of the second grating test pattern are formed on top of grating lines of the first grating test pattern.	Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figures 2a-2b - In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13.
227. The structure of claim 226, further comprising: a first gap from a left edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed on top of the first grating line of the first grating test pattern; and	Paragraph 31; Figures 2a-2b - The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1...
a second gap from the right edge of the first grating line of the first grating test pattern to the right edge of the first grating line of the second grating test pattern.	Paragraph 31; Figures 2a-2b - ...and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2.
228. The structure of claim 226, further comprising: one or more material layers formed between the first grating test pattern and the second grating test pattern.	Paragraph 33; Figure 4a - FIGS. 4a and 4b show alternative embodiments... An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. The invention also encompasses embodiments such as the line on line configuration. where the lines in the second periodic structure 15 are placed on top of and aligned with the lines in the first periodic structure 13, as shown by the dotted lines in FIG. 4a.

	Paragraph 34; Figure 4b - In another embodiment, FIG 4b illustrates a first periodic structure of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
229. The structure of claim 225, wherein grating lines of the second grating test pattern are interlaced with grating lines of the first grating test pattern.	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other… The invention also relates to a method of making overlying or interlaced targets. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths, or duty cycles.
230. The structure of claim 229, further comprising: a first gap from a right edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern; and	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
a second gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern, wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
231. The structure of claim 229, further comprising: one or more material layers formed between the first grating test pattern and the second grating test pattern.	Paragraph 33; Figure 4a - FIGS. 4a and 4b show alternative embodiments… An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic

	structure 13 Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment… The first layer 31 of silicon substrate and the second layer 33 of resist are separated by an oxide layer 39.
232. The structure of claim 225, wherein the first and second grating test patterns include: a first grating having grating lines in a first orientation; and a second grating having grating lines in a second orientation perpendicular to the first orientation, wherein the second grating is adjacent to the first grating.	Paragraph 31; Figure 2c - To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c. Paragraph 36; Figure 2c - In one embodiment, another target 12 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
233. The structure of claim 232, wherein the first and second grating test patterns include: a third grating having grating lines in a third orientation, wherein the third orientation is 45 degrees relative to the first orientation; and a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation, wherein the fourth grating is adjacent to the third grating and the second grating.	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device… In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 36 - A third periodic structure 14 is placed over the first layer 31, and a fourth periodic structure 14 is placed over the second layer 33. The third periodic structure 14 is substantially perpendicular to the first periodic structure 13, and the fourth periodic structure 16 is substantially perpendicular to the second periodic structure 15.
234. The structure of claim 233, wherein the first, second, third, and fourth gratings are quadrants in a four-quadrant test pattern formed on the semiconductor wafer.	Paragraph 2 - Overlay error measurement requires specially designed marks to be strategically placed at various locations, normally in the scribe line area between dies, on the wafers for each process. The alignment of the two overlay targets from two consecutive processes is measured for a number of locations on the wafer, and the overlay error map across the wafer is analyzed to provide feedback for the alignment control of lithography steppers.
235. The structure of claim 225, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing

	optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. Paragraph 46; Figure 9a - In one embodiment, optical system 100 provides ellipsometric parameter values...The polarization of the reflected light is measured by the analyzer in module 105, and the signal processor 109 calculates the ellipsometric parameter values... The signal processor 109 uses the ellipsometric parameter values to derive polarization and phase information. Paragraph 49; Figure 10a - Analyzers 121, 119 collect positive first-order diffracted radiation 95 and negative first-order diffracted radiation 93, respectively. Light detection units 125, 123 detect the positive first-order diffracted radiation 95 and the negative first-order diffracted radiation 93, respectively, collected by analyzers 121, 119, respectively, to provide output signals 85. A signal processor 109 determines any misalignment between the structures from the output signals 85, preferably by comparing the output signals 85 to a reference signal. In one embodiment, the signal processor 109 calculates a derived signal from the output signals 85. The derived signal is a differential signal between the positive first-order diffracted radiation 95 and the negative first-order diffracted radiation 93. The differential signal can indicate a differential intensity, a differential polarization angle, or a differential phase. Paragraph 50 - To determine differential phase, optical system 110 in one embodiment uses an ellipsometric arrangement comprising ... Paragraph 52; Figure 10a - To determine differential intensity, in one embodiment, the analyzers 119, 121 are positioned without relative rotation at the polarization angle of the first-order diffracted radiation .93, 95. Preferably, at the polarization angle where the intensity of the diffracted radiation is a maximum, the intensity of the positive first-order diffracted radiation 95 and the intensity of the negative first-order diffracted intensity 93 is detected by the detectors 125, 123. Differential intensity is calculated by subtracting the intensity for the negative first-order diffracted radiation 93 from the intensity for the positive first-order diffracted radiation 95.

236. A method of obtaining periodic structure overlay measurements, the method comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets… Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 8 - The invention also relates to a method of detecting misalignment between two layers of a device.
forming a first periodic structure using a first layer mask;	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
forming a second periodic structure using a second layer mask,	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
wherein the first and second periodic structures have the same pitch;	Paragraph 31; Figure 2a - In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2… The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1.
measuring the first and second periodic structures using an optical metrology equipment; and	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a

	metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 8 - The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal… In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 11- The invention also relates to an apparatus for detecting misalignment of overlying or interlaced periodic structures. The apparatus comprises a source, at least one analyzer, at least one detector, and a signal processor to determine misalignment of overlying or interlaced periodic structures. Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures.
measuring the alignment of the second layer mask to the first layer mask based on the measurement of the first and second periodic structures.	Paragraph 8 - The misalignment between the structures is determined from the output signal or the derived signal. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15.
237. The method of claim 236, wherein grating lines of the second periodic structure are formed on top of grating lines of the first periodic structure.	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. The invention also relates to a method of making overlying or interlaced targets.

	Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figures 2a-2b - In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13.
238. The method of claim 237, wherein a first distance measures a gap from a left edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed on top of the first grating line of the first periodic structure.	Paragraph 31; Figures 2a-2b - The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1...
239. The method of claim 238, wherein a second distance measures a gap from a right edge of the first grating line of the first periodic structure to a right edge of the first grating line of the second periodic structure.	Paragraph 31; Figures 2a-2b - ...and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2.
240. The method of claim 237, further comprising: forming one or more material layers between the first periodic structure and the second periodic structure.	Paragraph 33; Figure 4a - FIGS. 4a and 4b show alternative embodiments... An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. The invention also encompasses embodiments such as the line on line configuration. where the lines in the second periodic structure 15 are placed on top of and aligned with the lines in the first periodic structure 13, as shown by the dotted lines in FIG. 4a. Paragraph 34; Figure 4b - In another embodiment, FIG 4b illustrates a first periodic structure of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
241. The method of claim 236, wherein grating lines of the second periodic structure are interlaced with grating lines of the first periodic structure.	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other... The invention also relates to a method of making overlying or interlaced targets. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an

	embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths, or duty cycles.
242. The method of claim 241, wherein a first distance measures a gap from a right edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed adjacent to the first grating line of the first periodic structure.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
243. The method of claim 242, wherein a second distance measures a gap from a right edge of the first grating line of the second periodic structure to a left edge of a second grating line of the first periodic structure, wherein the first grating line of the second periodic structure is formed between the first and second grating lines of the first periodic structure.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
244. The method of claim 241, further comprising: forming one or more material layers between the first periodic structure and the second periodic structure.	Paragraph 33; Figure 4a - FIGS. 4a and 4b show alternative embodiments… An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13 Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment… The first layer 31 of silicon substrate and the second layer 33 of resist are separated by an oxide layer 39.
245. The method of claim 236, wherein the first and second periodic structures include: a first grating set having grating lines set in a first orientation; and a second grating set having grating lines set in a second orientation perpendicular to the first orientation, wherein the second grating set is adjacent to the first grating set.	Paragraph 31; Figure 2c - To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c. Paragraph 36; Figure 2c - In one embodiment, another target 12 is placed substantially perpendicular to target 11, as shown in FIG. 2c.

246. The method of claim 236, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. Paragraph 46; Figure 9a - In one embodiment, optical system 100 provides ellipsometric parameter values...The polarization of the reflected light is measured by the analyzer in module 105, and the signal processor 109 calculates the ellipsometric parameter values... The signal processor 109 uses the ellipsometric parameter values to derive polarization and phase information. Paragraph 49; Figure 10a - Analyzers 121, 119 collect positive first-order diffracted radiation 95 and negative first-order diffracted radiation 93, respectively. Light detection units 125, 123 detect the positive first-order diffracted radiation 95 and the negative first-order diffracted radiation 93, respectively, collected by analyzers 121, 119, respectively, to provide output signals 85. A signal processor 109 determines any misalignment between the structures from the output signals 85, preferably by comparing the output signals 85 to a reference signal. In one embodiment, the signal processor 109 calculates a derived signal from the output signals 85. The derived signal is a differential signal between the positive first-order diffracted radiation 95 and the negative first-order diffracted radiation 93. The differential signal can indicate a differential intensity, a differential polarization angle, or a differential phase. Paragraph 50 - To determine differential phase, optical system 110 in one embodiment uses an ellipsometric arrangement comprising ... Paragraph 52; Figure 10a - To determine differential intensity, in one embodiment, the analyzers 119, 121 are positioned without relative rotation at the polarization angle of the first-order diffracted radiation .93, 95. Preferably,

	at the polarization angle where the intensity of the diffracted radiation is a maximum, the intensity of the positive first-order diffracted radiation 95 and the intensity of the negative first-order diffracted intensity 93 is detected by the detectors 125, 123. Differential intensity is calculated by subtracting the intensity for the negative first-order diffracted radiation 93 from the intensity for the positive first-order diffracted radiation 95.
247. A method of obtaining overlay measurements, the method comprising: forming a first periodic structure using a first layer mask; forming a second periodic structure using a second layer mask, wherein the first and second periodic structures have the same pitch, and wherein the first and second periodic structures have: a first grating set having grating lines set in a first orientation, and a second grating set having grating lines set in a second orientation perpendicular to the first orientation; measuring the first and second periodic structures including the first and second grating sets using an optical metrology equipment; and measuring the alignment of the second layer mask to the first layer mask in the first and second orientations based on the measurement of the first and second periodic structures including the first and second grating sets.	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets, and, in particular, to a metrology system employing diffracted light for detecting misalignment of such structures. Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figure 2c - In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
248. The method of claim 247, wherein a first distance measures a gap from a left edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first	Paragraph 31; Figures 2a-2b - The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure

grating line of the first periodic structure is formed on top of the first grating line of the second periodic structure, and wherein a second distance measures a gap from a right edge of the first grating line of the first periodic structure to a right edge of the first grating line of the second periodic structure.	13 and the right edge of the second periodic structure 15 is d.sub.2… In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1. To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
249. The method of claim 247, wherein a first distance measures a gap from a right edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed adjacent to the first grating line of the first periodic structure, wherein a second distance measures a gap from a right edge of the first grating line of the second periodic structure to a left edge of a second grating line of the first periodic structure, and wherein the first grating line of the second periodic structure is formed between the first and second grating lines of the first periodic structure.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b, and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
250. The method of claim 247 therein the first and second periodic structures are formed on a semiconductor wafer, and wherein the first and second periodic structures are measured using the optical metrology equipment without reloading the semiconductor wafer.	Paragraph 37 - …The first selected width CD1 is measured before placing the second periodic structure 15 on the device 17. After forming the target, the second selected width CD2 alone can be measured in the CD region 21. In a separate measurement, the misregistration is determined in an overlay region 19 where both the first 13 and second 15 periodic structures lie. Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. The output signal 85 is used directly to determine misalignment from the intensity of the zero-order diffracted radiation 83. In a preferred embodiment, the misalignment is determined by

	comparing the intensity with a reference signal, such as a reference signal from a calibration wafer or a database, compiled as explained below. In one embodiment, the signal processor 109 calculates a derived signal from the output signal 85 and determines misalignment from the derived signal. The derived signal can include polarization or phase information. In this embodiment, the misalignment is determined by comparing the derived signal with a reference signal. Paragraph 46 - In one embodiment, optical system 100 provides ellipsometric parameter values, which are used to derive polarization and phase information. In this embodiment, the source 102 includes a light source 101 and a polarizer in module 103. Additionally, a device 104 causes relative rotational motion between the polarizer in module 103 and the analyzer in module 105. Device 104 is well known in the art and is not described for this reason.
251. A structure formed on a semiconductor wafer for obtaining overlay measurements, the structure comprising:	Paragraph 1 - The invention relates in general to metrology systems for measuring periodic structures such as overlay targets… Paragraph 3 - A key process control parameter in the manufacturing of integrated circuits is the measurement of overlay target alignment between successive layers on a semiconductor wafer. Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other.
a first periodic structure formed on the semiconductor wafer using a first layer mask; and	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device.
a second periodic structure formed on the semiconductor wafer using a second layer mask,	Paragraph 6 - In one embodiment, either the first periodic structure or the second periodic structure has at least two sets of interlaced grating lines having different periods, line widths or duty cycles. Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second

	layer 33 of the device.
wherein the first and second periodic structures have the same pitch,	Paragraph 31; Figures 2a-2b - In one embodiment, as illustrated in FIG. 2a, the first periodic structure 13 has a first selected width CD1, and the second periodic structure 15 has a second selected width CD2… The pitch, also called the period or the unit cell, of a periodic structure is the distance after which the pattern is repeated. The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1, and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2. In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13. In other words, when the second periodic structure 15 is perfectly centered over the first periodic structure 13, the misregistration is zero, and d.sub.1=d.sub.2. In this embodiment, the misregistration is indicated by d.sub.2-d.sub.1.
wherein the first and second periodic structures are measured using an optical metrology equipment, and	Paragraph 8 - The overlying or interlaced periodic structures are illuminated by incident radiation. The diffracted radiation from the overlying or interlaced periodic structures is used to provide an output signal. In one embodiment, a signal is derived from the output signal… In one embodiment, the output signal or the derived signal is compared with a reference signal. A database that correlates the misalignment with data related to diffracted radiation can be constructed. Paragraph 11- The invention also relates to an apparatus for detecting misalignment of overlying or interlaced periodic structures. The apparatus comprises a source, at least one analyzer, at least one detector, and a signal processor to determine misalignment of overlying or interlaced periodic structures. Paragraph 20; Figure 9a - FIG. 9a is a schematic block diagram of an optical system that measures zero-order diffraction from overlying or interlaced periodic structures.
wherein the alignment of the second layer mask to the first layer mask is measured based on the measurement of the first and second periodic structures.	Paragraph 29 - The pattern for the first periodic structure 13 is in the same mask as the pattern for a first layer 31 of the device, and the pattern for the second periodic structure 15 is in the same mask as the pattern for a second layer 33 of the device. Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33.

	Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15.
252. The structure of claim 251, wherein grating lines of the second periodic structure are formed on top of grating lines of the first periodic structure.	Paragraph 30 - The first periodic structure 13 has the same alignment as the first layer 31, since the same mask was used for the pattern for the first periodic structure 13 and for the pattern for the first layer 31. Similarly, the second periodic structure 15 has the same alignment as the second layer 33. Thus, any overlay misregistration error in the alignment between the first layer 31 and the second layer 33 will be reflected in the alignment between the first periodic structure 13 and the second periodic structure 15. Paragraph 31; Figures 2a-2b - In a preferred embodiment, when layers 31, 33 are properly aligned relative to each other, the second periodic structure 15 is centered over the first periodic structure 13.
253. The structure of claim 252, further comprising: a first gap from a left edge of a first grating of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed on top of the first grating line of the first periodic structure; and	Paragraph 31; Figures 2a-2b - The distance between the left edge of the first periodic structure 13 and the left edge of the second periodic structure 15 is d.sub.1...
a second gap from a right edge of the first grating line of the first periodic structure to a right edge of the first grating line of the second periodic structure.	Paragraph 31; Figures 2a-2b - ...and the distance between the right edge of the first periodic structure 13 and the right edge of the second periodic structure 15 is d.sub.2.
254. The structure of claim 252, further comprising: one or more material layers formed between the first periodic structure and the second periodic structure.	Paragraph 33; Figure 4a - FIGS. 4a and 4b show alternative embodiments... An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13. The invention also encompasses embodiments such as the line on line configuration. where the lines in the second periodic structure 15 are placed on top of and aligned with the lines in the first periodic structure 13, as shown by the dotted lines in FIG. 4a. Paragraph 34; Figure 4b - In another embodiment, FIG 4b illustrates a first periodic structure of tungsten etched in a first layer 31 of oxide and a second periodic structure 15 of resist with a second layer 33 of resist. The first layer 31 and the second layer 33 are separated by an aluminum blanket 37.
255. The structure of claim 251, wherein grating lines of the second periodic structure are interlaced with grating lines of the first periodic structure.	Paragraph 6 - A target for determining misalignment between two layers of a device has two periodic structures of lines and spaces on the two different layers of a device. The two periodic structures overlie or are interlaced with each other... The invention also relates to a method of making overlying or

	interlaced targets. Paragraph 38; Figures 5a-5b - FIGS. 5a and 5b are cross-sectional views of an embodiment of a target having interlaced gratings. The first periodic structure 13 or the second periodic structure 15 has at least two interlaced grating lines having different periods, line widths, or duty cycles.
256. The structure of claim 255, further comprising: a first gap from a right edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed adjacent to the first grating line of the first periodic structure; and	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
a second gap from a right edge of the first grating line of the second periodic structure to a left edge of a second grating line of the first periodic structure, wherein the first grating line of the second periodic structure is formed between the first and second grating lines of the first periodic structure.	Paragraph 39; Figures 5a-5b - In the embodiment shown in FIGS. 5a and 5b, the first periodic structure 13 has two interlaced grating lines 51, 53. The first interlaced grating lines 51 have a line-width L.sub.1, and the second interlaced grating lines 53 have a line-width L.sub.2. The second periodic structure 15, as shown in FIG. 5b, has a line-width L.sub.3 and is centered between the first interlaced grating lines 51 and the second interlaced grating lines 53. The distance between the right edge of the first interlaced grating 51 and the adjacent left edge of the second interlaced grating 53 is represented by b and the distance between the right edge of the second periodic structure 15 and the adjacent left edge of the second interlaced grating 53 is represented by c.
257. The structure of claim 255, further comprising: one or more material layers formed between the first periodic structure and the second periodic structure.	Paragraph 33; Figure 4a - FIGS. 4a and 4b show alternative embodiments... An oxide layer 34 and a uniform polysilicon layer 35 are deposited between the first layer 31 of silicon and the second layer 33 of resist. The configuration in FIG. 4a shows a line on space configuration, where the second periodic structure 15 is placed aligned with the spaces between the first periodic structure 13 Paragraph 41; Figure 6 - FIG. 6 shows an alternative embodiment... The first layer 31 of silicon substrate and the second layer 33 of resist are separated by an oxide layer 39.
258. The structure of claim 251, wherein the first and second periodic structures include: a first grating set having grating lines set in a first orientation; and a second grating set having grating lines set in a second orientation	Paragraph 31; Figure 2c - To obtain misregistration in both the X and Y directions of the XY coordinate system, another target 12 comprising two periodic structures 14, 16 similar to target 11 is placed substantially perpendicular to target 11, as shown in FIG. 2c.

perpendicular to the first orientation, wherein the second grating set is adjacent to the first grating set.	Paragraph 36; Figure 2c - In one embodiment, another target 12 is placed substantially perpendicular to target 11, as shown in FIG. 2c.
259. The structure of claim 251, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.	Paragraph 45; Figure 9a - FIG. 9a shows an optical system 100 using incident radiation beam 81 with an oblique angle of incidence and detecting zero-order diffracted radiation 83. A source 102 provides polarized incident radiation beam 81 to illuminate periodic structures on a wafer 91. The incident radiation beam may be substantially monochromatic or polychromatic. The source 102 comprises a light source 101 and optionally a collimating/ focusing/ polarizing optical module 103. The structures diffract zero-order diffracted radiation 83. A collimating/ focusing/ analyzing optical module 105 collects the zero-order diffracted radiation 83, and a light detection unit 107 detects the zero-order diffracted radiation 83 collected by the analyzer in module 105 to provide an output signal 85. A signal processor 109 determines any misalignment between the structures from the output signal 85. Paragraph 46; Figure 9a - In one embodiment, optical system 100 provides ellipsometric parameter values...The polarization of the reflected light is measured by the analyzer in module 105, and the signal processor 109 calculates the ellipsometric parameter values... The signal processor 109 uses the ellipsometric parameter values to derive polarization and phase information. Paragraph 49; Figure 10a - Analyzers 121, 119 collect positive first-order diffracted radiation 95 and negative first-order diffracted radiation 93, respectively. Light detection units 125, 123 detect the positive first-order diffracted radiation 95 and the negative first-order diffracted radiation 93, respectively, collected by analyzers 121, 119, respectively, to provide output signals 85. A signal processor 109 determines any misalignment between the structures from the output signals 85, preferably by comparing the output signals 85 to a reference signal. In one embodiment, the signal processor 109 calculates a derived signal from the output signals 85. The derived signal is a differential signal between the positive first-order diffracted radiation 95 and the negative first-order diffracted radiation 93. The differential signal can indicate a differential intensity, a differential polarization angle, or a differential phase. Paragraph 50 - To determine differential phase, optical system 110 in one embodiment uses an ellipsometric arrangement comprising ...

	Paragraph 52; Figure 10a - To determine differential intensity, in one embodiment, the analyzers 119, 121 are positioned without relative rotation at the polarization angle of the first-order diffracted radiation .93, 95. Preferably, at the polarization angle where the intensity of the diffracted radiation is a maximum, the intensity of the positive first-order diffracted radiation 95 and the intensity of the negative first-order diffracted intensity 93 is detected by the detectors 125, 123. Differential intensity is calculated by subtracting the intensity for the negative first-order diffracted radiation 93 from the intensity for the positive first-order diffracted radiation 95.

Appendix B
The Proposed Count

Claim 18 of U.S. Patent No. 6,772,084	**OR**	**Claim 93 of Application No. 10/699,153**
1. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:		78. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:
forming a periodic grating on the wafer having:		forming a periodic grating on the wafer having:
a first set of gratings,		a first set of gratings,
wherein the first set of gratings are formed on the wafer using a first mask, and		wherein the first set of gratings are formed on the wafer using a first mask, and
a second set of gratings,		a second set of gratings,
wherein the second set of gratings are formed on the wafer using a second mask,		wherein the second set of gratings are formed on the wafer using a second mask,
wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;		wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;
selecting a wavelength;		
measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer using the selected wavelength; and		measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer; and
determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.		determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.
12. The method of claim 1 further comprising:		88. The method of claim 78 further comprising:
generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,		generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,
wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.		wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.
18. The method of claim 12, wherein the determining the misalignment between the first and second sets of gratings comprises:		93. The method of claim 88, wherein the determining the misalignment between the first and second sets of gratings comprises:

Claim 18 of U.S. Patent No. 6,772,084	OR	Claim 93 of Application No. 10/699,153
comparing the measured diffraction signal to the generated set of diffraction signals; and		comparing the measured diffraction signal to the generated set of diffraction signals; and
determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.		determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.

Appendix C
Interfering Claims of the 6,819,426 Sezginer et al. Patent

1. A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising,

forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, zero or more layers of other materials separating layers A and B, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B;

observing the overlaid diffraction gratings using an optical instrument capable of measuring any one or more of transmission, reflectance, or ellipsometric parameters as a function of any one or more of wavelength, polar angle of incidence, azimuthal angle of incidence, or polarization of the illumination and detection; and

determining the offset between the gratings from the measurements from the optical instrument using an optical model, wherein the optical model accounts for the diffraction of the electromagnetic waves by the gratings and the interaction of the gratings with each other's diffracted field;

wherein at least one layer between the grating in layer A and the grating in layer B is opaque in the wavelength range of the optical instrument, and the presence of the grating in layer A causes a grating-shaped topography on the surface of the opaque layer.

2. A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising,

forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, zero or more layers of other materials separating layers A and B, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B;

observing the overlaid diffraction gratings using an optical instrument capable of measuring any one or more of transmission, reflectance, or ellipsometric parameters as a function of any one or more of wavelength, polar angle of incidence, azimuthal angle of incidence, or polarization of the illumination and detection; and

determining the offset between the gratings from the measurements from the optical instrument using an optical model, wherein the optical model accounts for the diffraction of the electromagnetic waves by the gratings and the interaction of the gratings with each other's diffracted field;

wherein the optical model represents the electromagnetic field in the gratings and in the layers between the gratings as a sum of more than one diffracted orders.

8. A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:

forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, zero or more layers of other materials separating layers A and B, the two gratings substantially overlapping when

viewed from a direction that is perpendicular to the surfaces of A and B,

observing the overlaid diffraction gratings using an optical instrument capable of measuring any one or more of transmission, reflectance, or ellipsometric parameters as a function of any one or more of wavelength, polar angle of incidence, azimuthal angle of incidence, or polarization of the illumination and detection; and

determining the offset between the gratings from the measurements from the optical instrument using an optical model, wherein the optical model accounts for the diffraction of the electromagnetic waves by the gratings and the interaction of the gratings with each other's diffracted field;

wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch being substantially different from each other.

Appendix D
Interfering Claims of the 6,772,084 Bischoff et al. Patent

1. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:

forming a periodic grating on the wafer having:

a first set of gratings,

wherein the first set of gratings are formed on the wafer using a first mask, and

a second set of gratings,

wherein the second set of gratings are formed on the wafer using a second mask,

wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;

selecting a wavelength;

measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer using the selected wavelength; and

determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.

2. The method of claim 1, wherein the measured diffraction signal is a zero-order diffraction.

3. The method of claim 2, wherein only the zero-order diffraction is measured.

4. The method of claim 1, wherein the diffraction signal is measured using an optical metrology system.

5. The method of claim 4, wherein the optical metrology system includes an ellipsometer.

6. The method of claim 4, wherein the optical metrology system includes a reflectometer.

7. The method of claim 1, wherein the diffraction signal is measured using an incident signal with a normal incidence angle.

8. The method of claim 1, wherein the diffraction signal is measured using an incident signal with an oblique incidence angle.

9. The method of claim 8, wherein the incident signal has an azimuthal angle of zero degrees.

11. The method of claim 10, wherein measuring the diffraction signal includes:
measuring the amplitude of the diffraction signal.

12. The method of claim 1 further comprising:

generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,

wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.

13. The method of claim 12 further comprising:

generating a response curve of the correspondence between the different possible misalignments of the first and second sets of gratings and the set of diffraction signals.

15. The method of claim 12 further comprising:

determining the intended asymmetric alignment between the first and second sets of gratings based on the generated set of diffraction signals and range of possible alignments.

16. The method of claim 12, wherein the set of diffraction signals are generated empirically.

17. The method of claim 12, wherein the set of diffraction signals are generated using modeling.

18. The method of claim 12, wherein the determining the misalignment between the first and second sets of gratings comprises:

comparing the measured diffraction signal to the generated set of diffraction signals; and

determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.

28. The method of claim 1,

wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and

wherein the ridges of the first and second sets of gratings alternate.

29. The method of claim 28,

wherein the ridges of the first and second sets of gratings include centerlines having a spacing between the centerlines of the ridges of the first and second sets of gratings, and

wherein the first and second sets of gratings are symmetrically aligned when the spacing between the centerlines is uniform and asymmetrically aligned when the spacing between the centerlines is non-uniform.

30. The method of claim 29, wherein the intended asymmetric alignment includes an offset from symmetrical alignment of the first and second sets of gratings.

32. The method of claim 1,

wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and

wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

33. The method of claim 32,

wherein the ridges of the first and second sets of gratings include centerlines, and

wherein the first and second sets of gratings are symmetrically aligned when the

centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

34. The method of claim 33, wherein the intended asymmetric alignment includes an offset from symmetrical alignment of the first and second sets of gratings.

36. The method of claim 1, wherein forming a periodic grating on the wafer comprises:
forming a periodic grating in a first metrology field on the wafer;
forming a periodic grating in a second metrology field on the wafer,
wherein the first and second metrology fields are separated by a distance on the wafer;
obtaining overlay measurements from the first and second metrology fields; and
computing a tilt error are based on the obtained overlay measurements.

38. A method of obtaining overlay measurements for a semiconductor wafer using a periodic grating, the method comprising:

forming a first set of gratings of the periodic grating on the wafer;

forming a second set of gratings of the periodic grating on the wafer,

wherein the first and second sets of gratings are formed using separate masks, and

wherein the second set of gratings are intended to be formed on the wafer with an intended asymmetrical alignment from the first set of gratings when the separate masks are in alignment;

generating a set of diffraction signals at a selected wavelength for a range of possible misalignments between the first and second sets of gratings,

wherein each of the diffraction signal in the generated set of diffraction signals corresponds to a possible misalignment between the first and second sets of gratings;

measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer,

wherein the diffraction signal is measured using the selected wavelength; and

determining a misalignment between the first and second sets of gratings based on the measured diffraction signal and the generated set of diffraction signals.

39. The method of claim 38, wherein the determining the misalignment between the first and second sets of gratings comprises:

comparing the measured diffraction signal to the generated set of diffraction signals; and

determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.

43. The method of claim 38, wherein the measured diffraction signal is a zero-order diffraction.

44. The method of claim 38 further comprising:

generating a plurality of sets of diffraction signals at various wavelengths, polarizations, and/or incidence angles.

52. The method of claim 38,

wherein the first and second sets of gratings include a plurality of ridges that alternate

with a spacing between the ridges,

wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.

53. The method of claim 38,

wherein the first and second sets of gratings include a plurality of ridges with centerlines,

wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings, and

wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

55. A method of obtaining overlay measurements for a semiconductor wafer using a periodic grating formed on the wafer, the method comprising:

obtaining the wafer, wherein the period grating on the wafer comprises:

a first set of grating that were formed on the wafer using a first mask,

a second set of gratings that were formed on the wafer using a second mask,

wherein the first and second sets of gratings were intended to be formed on the wafer with an asymmetric alignment when the first mask and second mask are in alignment;

generating a set of diffraction signals at a selected wavelength for a plurality of possible misalignments between the first and second sets of gratings;

measuring a diffraction signal of the first and second sets of gratings from the obtained wafer,

wherein the diffraction signal is measured using the selected wavelength, and

wherein the measured diffraction signal is a zero-order diffraction;

comparing the measured diffraction signal to the generated set of diffraction signals; and

determining an amount and direction of misalignment between the first and second sets of gratings on the obtained wafer based on the possible alignment that corresponds to the diffraction signal from the set of diffraction signals that matches the measured diffraction signal.

57. The method of claim 55,

wherein the periodic grating on the wafer further comprises:

a first periodic grating oriented for obtaining overlay measurements in a first coordinate direction, and

a second periodic grating oriented for obtaining overlay measurements in a second coordinate direction; and

wherein measuring a diffraction signal further comprises:

measuring a first diffraction signal from the first periodic grating, and

measuring a second diffraction signal from the second periodic grating without rotating the wafer.

58. The method of claim 57, wherein the measured diffraction signals and the generated diffraction signals have amplitude ratios, and wherein the amplitude ratios of the measured diffraction signals are compared with the amplitude ratios of the generated diffraction signals.

60. The method of claim 57, wherein the diffraction signals are measured using an oblique and conical incident signal.

62. The method of claim 55, wherein the diffraction signal is measured using a normal incidence angle.

63. The method of claim 55, wherein the diffraction signal is measured using an oblique incidence angle with an azimuthal angle of zero degrees.

68. The method of claim 55,

wherein the first and second sets of gratings include a plurality of ridges that alternate with a spacing between the ridges,

wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.

69. The method of claim 55,

wherein the first and second sets of gratings include a plurality of ridges with centerlines,

wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings, and

wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

70. A system to obtain overlay measurements of a semiconductor wafer, the system comprising:

a periodic grating formed on the wafer comprising:

a first set of gratings formed using a first mask,

a second set of gratings formed using a second mask, and

wherein the first and second sets of gratings are intended to be formed with an asymmetric alignment when the first mask and second mask are in alignment; and

an optical metrology system comprising:

a detector configured to measure a diffraction signal from the first and second sets of gratings using a selected wavelength, and

a signal processing unit configured to determine a misalignment between the first and second sets of gratings based on the measured diffraction signal.

71. The system of claim 70, wherein the signal processing unit is configured to compare the measured diffraction signal to a set of diffraction signals generated for a plurality of possible alignments between the first and second sets of gratings.

72. The system of claim 70, wherein the periodic grating further comprises:

a first periodic grating oriented in a first coordinate direction; and

a second periodic grating oriented in a second coordinate direction,

wherein overlay measurements can be obtained in the first and second coordinate directions using the first and second periodic gratings without rotating the wafer.

74. The system of claim 72, wherein the optical metrology system comprises:
a source configured to produce an oblique and conical incident signal.

75. The system of claim 70, wherein the optical metrology system comprises:
a source configured to produce a normal incident signal.

76. The system of claim 70, wherein the optical metrology system comprises:
a source configured to produce an incident signal having an oblique incidence angle and an azimuthal angle of zero degrees.

77. The system of claim 70, wherein the periodic grating comprises:
a first portion with the first and second sets of gratings having a first asymmetric alignment; and
a second portion with the first and second sets of gratings having a second asymmetric alignment.

78. The system of claim 77,
wherein the detector is configured to measure a first diffraction signal from the first portion of the period grating and a second diffraction signal from the second portion of the periodic grating, and
wherein the signal processor is configured to determine the amount and direction of misalignment between the first and second masks used to form the first and second sets of gratings based on the measured first and second diffraction signals.

79. The system of claim 78, wherein the signal processor is configured to determine the alignment of the first and second sets of gratings by comparing the difference between the measured first and second diffraction signals to a set of difference signals generated for a plurality of possible misalignments between the first and second sets of gratings.

80. The system of claim 78, wherein the periodic grating further comprises:
a third portion having only the first set of gratings; and
a fourth portion having only the second set of gratings.

81. The system of claim 80, wherein the optical metrology system comprises:
a library of simulated-diffraction signals having a set of theoretical geometry of the first and second sets of gratings;
wherein the detector is configured to measure a diffraction signal from the third portion and a diffraction signal from the fourth portion; and
wherein the signal processing unit is configured to compare the measured diffraction signal to the simulated-diffraction signals to determine the geometry of the first and second sets of gratings.

83. The system of claim 70, wherein the first and second sets of gratings include a plurality of ridges that alternate with a spacing between the ridges; and

wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.

84. The system of claim 70, wherein the first and second sets of gratings include a plurality of ridges with centerlines;

wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings; and

wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

85. A computer-readable storage medium containing computer executable instructions for causing a computer to obtain overlay measurements for a semiconductor wafer, comprising instructions for:

measuring a diffraction signal at a selected wavelength of a first set of grating and a second set of gratings of a periodic grating formed on the wafer, wherein

the first set of gratings were formed using a first mask,

the second set of gratings were formed using a second mask, and

wherein the first and second sets of gratings were intended to be formed on the wafer with an asymmetric alignment when the first mask and second mask are in alignment;

generating a set of diffraction signals at the selected wavelength for a plurality of possible misalignments between the first and second sets of gratings;

determining a misalignment of the first and second sets of gratings formed on the wafer based on the measured diffraction signal and the generated set of diffraction signals; and

determining the amount and direction of misalignment between the first and second masks based on the determined misalignment of the first and second sets of gratings formed on the wafer.

87. The computer-readable storage medium of claim 85, further comprising instructions for:

obtaining the geometry of the first set of gratings; and

obtaining the geometry of the second set of gratings,

wherein the generated set of diffraction signals is generated based on the obtained geometry of the first and second sets of gratings.

88. The computer-readable storage medium of claim 87, further comprising instructions for:

measuring diffraction signals of the first set of gratings;

measuring diffraction signals of the second set of gratings; and

comparing the measured diffraction signals to a library of simulated-diffraction signals having a set of theoretical geometry of the first and second sets of gratings.

89. The computer-readable storage medium of claim 88, wherein the diffraction signals of the first set of gratings are measured from a third portion of the grating having only the first set of gratings, and the diffraction signals of the second set of gratings are measured from a fourth portion of the grating having only the second set of gratings.

91. The computer-readable storage medium of claim 85, further comprising instructions for:
measuring a first diffraction signal from a first periodic grating;
determining the amount and direction of misalignment between the first and second mask in a first coordinate direction using the first measured diffraction signal;
measuring a second diffraction signal from a second periodic grating without rotating the wafer; and
determining the amount and direction of misalignment between the first and second mask in a second coordinate direction using the second measured diffraction signal.

Appendix E
Interfering Claims of the 6,804,005 Bischoff et al. Patent

1. method of obtaining overlay measurements for a semiconductor wafer, the method comprising:

forming a periodic grating on the wafer having:

a first set of gratings,

wherein the first set of gratings are formed on the wafer using a first mask, and

a second set of gratings,

wherein the second set of gratings are formed on the wafer using a second mask;

obtaining zero-order cross polarization measurements of a portion of the periodic grating after forming the first and second sets of gratings; and

determining any overlay error between the first and second masks used to form the first and second sets of gratings based on the obtained zero-order cross polarization measurements.

2. The method of claim 1, wherein obtaining zero-order cross polarization measurements comprises:

obtaining a first zero-order cross polarization measurement; and

obtaining a second zero-order cross polarization measurement,

wherein the second zero-order cross polarization measurement has a polarization opposite that of the first zero-order cross polarization measurement.

3. The method of claim 2, wherein the first and second zero-order cross polarization measurements are obtained from the same site on the periodic grating.

8. The method of claim 2, wherein determining any overlay error comprises:

comparing the difference between the first zero-order cross polarization measurement and the second zero-order cross polarization measurement,

wherein an overlay error exists between the first and second masks when there is a difference between the first and second zero-order cross polarization measurements.

9. The method of claim 2 further comprising:

obtaining a set of first zero-order cross polarization measurements for a range of possible misalignments between the first and second masks; and

obtaining a set of second zero-order cross polarization measurements for a range of possible misalignments between the first and second masks.

10. The method of claim 9 further comprising:

generating a first response curve based on the set of first zero-order cross polarization measurements, wherein the first response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of first zero-order cross polarization measurements; and

generating a second response curve based on the set of second zero-order cross polarization measurements,

wherein the second response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of second zero-order cross

polarization measurements.

13. The method of claim 10, wherein the response curves are generated using modeling.

18. The method of claim 2, wherein the first zero-order cross polarization measurement includes TE polarization and the second zero-order cross polarization measurement includes TM polarization.

19. The method of claim 2, wherein the first zero-order cross polarization measurement includes TM polarization and the second zero-order cross polarization measurement includes TE polarization.

20. The method of claim 1, wherein the zero-order cross polarization measurements are obtained using an optical metrology system.

21. The method of claim 20, wherein the optical metrology system includes a reflectometer.

22. The method of claim 20, wherein the optical metrology system includes an ellipsometer.

23. The method of claim 22, wherein the ellipsometer includes:

a polarizer; and

an analyzer,

wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order cross polarization measurement, and

wherein the polarizer and the analyzer are set to a second angular setting to obtain a second zero-order cross polarization measurement.

27. The method of claim 1,

wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and

wherein the ridges of the first and second sets of gratings alternate.

28. The method of claim 27,

wherein the ridges of the first and second sets of grating include centerlines having a spacing between the centerlines of the ridges of the first and second sets of gratings; and

wherein the first and second sets of gratings are formed with the spacing between the centerlines uniform when the first and second masks are aligned without an overlay error.

29. The method of claim 1,

wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and

wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

30. The method of claim 29,

wherein the ridges of the first and second sets of gratings include centerlines, and

wherein the first and second sets of gratings are formed with the centerlines of the ridges aligned when the first and second masks are aligned without an overlay error.

31. The method of claim 1, wherein the periodic grating is formed from isotropic materials.

32. The method of claim 1, wherein the zero-order cross polarization measurements are obtained using an oblique and conical incident signal.

33. The method of claim 1, wherein the first and second sets of gratings are formed from different materials and have the same height.

34. The method of claim 1, wherein the first and second sets of gratings are formed from different materials and have different heights.

35. The method of claim 1, wherein the first and second sets of gratings are formed from the same material and have different linewidths.

36. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:

forming a periodic grating on the wafer having: a first set of periodic gratings, and a second set of periodic gratings,

wherein the first and second sets of periodic gratings are formed using separate masks;

obtaining zero-order cross polarization measurements from the periodic grating after forming the first and second sets of gratings,

wherein the zero-order cross polarization measurements are obtained using an oblique and conical incident angle; and

determining any overlay error associated with the formation of the first and second sets of gratings based on the obtained zero-order cross polarization measurements.

37. The method of claim 36, wherein obtaining zero-order cross polarization measurements comprises:

obtaining a first zero-order cross polarization measurement; and

obtaining a second zero-order cross polarization measurement,

wherein the second zero-order cross polarization measurement has a polarization opposite that of the first zero-order cross polarization measurement.

41. The method of claim 37, wherein the first zero-order cross polarization measurement includes TE polarization and the second zero-order cross polarization measurement includes TM polarization.

42. The method of claim 37, wherein the first zero-order cross polarization measurement includes TM polarization and the second zero-order cross polarization measurement includes TE polarization.

43. The method of claim 37, wherein the first and second zero-order cross polarization measurements are obtained from a single site on the periodic grating.

44. The method of claim 37 further comprising:

obtaining a set of first zero-order cross polarization measurements for a range of possible misalignments between the first and second gratings; and

obtaining a set of second zero-order cross polarization measurements for a range of possible misalignments between the first and second gratings.

45. The method of claim 44 further comprising:

generating a first response curve based on the set of first zero-order cross polarization measurements; and

generating a second response curve based on the set of second zero-order cross polarization measurements,

wherein the first and second response curves characterize a relationship between the different possible misalignments of the first and second gratings and the zero-order cross polarization measurements.

49. The method of claim 36,

wherein the zero-order cross polarization measurements are obtained using an ellipsometer having: a polarizer; and an analyzer,

wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order cross polarization measurement, and

wherein the polarizer and the analyzer are set to a second angular setting to obtain a second zero-order cross polarization measurement.

52. The method of claim 36,

wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and

wherein the ridges of the first and second sets of gratings alternate.

53. The method of claim 52,

wherein the ridges of the first and second sets of grating include centerlines having a spacing between the centerlines of the ridges of the first and second sets of gratings; and

wherein the first and second sets of gratings are formed with the spacing between the centerlines nonuniform when an overlay error exists.

54. The method of claim 36,

wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and

wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

55. The method of claim 54,

wherein the ridges of the first and second sets of gratings include centerlines, and

wherein the first and second sets of gratings are formed with the centerlines of the ridges misaligned when an overlay error exists.

56. The method of claim 36, wherein the periodic grating is formed from isotropic materials.

57. A method of obtaining overlay measurements for a semiconductor wafer having a periodic grating with a first set of gratings and a second set of gratings, the method comprising:

obtaining a first zero-order cross polarization measurement from the periodic grating; and

obtaining a second zero-order cross polarization measurement from the periodic grating,

wherein the first and second zero-order cross polarization measurements are obtained using an oblique and conical incident angle,

wherein the first and second zero-order cross polarization measurements are obtained from a single site on the periodic grating, and

wherein the second zero-order cross polarization measurement has a polarization opposite that of the first zero-order cross polarization measurement; and

determining any overlay error associated with the formation of the first and second sets of gratings based on the obtained first and second zero-order cross polarization measurements.

61. The method of claim 57, wherein the first zero-order cross polarization measurement includes TE polarization and the second zero-order cross polarization measurement includes TM polarization.

62. The method of claim 57, wherein the first zero-order cross polarization measurement includes TM polarization and the second zero-order cross polarization measurement includes TE polarization.

63. The method of claim 57, wherein the periodic grating is formed from isotropic materials.

64. The method of claim 57 further comprising:

obtaining a set of first zero-order cross polarization measurements for a range of possible misalignments between the first and second gratings; and

obtaining a set of second zero-order cross polarization measurements for a range of possible misalignments between the first and second gratings.

65. The method of claim 64 further comprising:

generating a first response curve based on the set of first zero-order cross polarization measurements; and

generating a second response curve based on the set of second zero-order cross polarization measurements,

wherein the first and second response curves characterize a relationship between the different possible misalignments of the first and second gratings and the zero-order cross polarization measurements.

69. The method of claim 57,

wherein the first and second zero-order cross polarization measurements are obtained using an ellipsometer having:

a polarizer; and

an analyzer,

wherein the polarizer and the analyzer are set to a first angular setting to obtain the first zero-order cross polarization measurement, and

wherein the polarizer and the analyzer are set to a second angular setting to obtain the second zero-order cross polarization measurement.

74. A system to obtain overlay measurements of a semiconductor wafer, the system comprising:

a periodic grating formed on the wafer comprising:

a first set of gratings formed using a first mask,

a second set of gratings formed using a second mask; and

an optical metrology system configured to:

obtain zero-order cross polarization measurements from the periodic grating after the first and second sets of gratings are formed on the wafer, and

determine any overlay error between the first and second masks used to form the first and second sets of gratings based on the obtained zero-order cross polarization measurements.

75. The system of claim 74, wherein the optical metrology system is configured to:

obtain a first zero-order cross polarization measurement; and

obtain a second zero-order cross polarization measurement,

wherein the second zero-order cross polarization measurement has a polarization opposite that of the first zero-order cross polarization measurement.

76. The system of claim 75, wherein the first and second zero-order cross polarization measurements are obtained from the same site on the periodic grating.

78. The system of claim 75, wherein the optical metrology system is configured to:

compare the difference between the first zero-order cross polarization measurement and the second zero-order cross polarization measurement,

wherein an overlay error exists when there is a difference between the first and second zero-order cross polarization measurements.

80. The system of claim 75, wherein the first zero-order cross polarization measurement includes TE polarization and the second zero-order cross polarization measurement includes TM polarization.

81. The system of claim 75, wherein the first zero-order cross polarization measurement includes TM polarization and the second zero-order cross polarization measurement includes TE polarization.

82. The system of claim 74, wherein the optical metrology system includes a reflectometer.

83. The system of claim 74, wherein the optical metrology system includes an ellipsometer.

84. The system of claim 83, wherein the ellipsometer includes:

a polarizer; and

an analyzer,

wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order cross polarization measurement, and

wherein the polarizer and the analyzer are set to a second angular setting to obtain a second zero-order cross polarization measurement.

88. The system of claim 74,

wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and

wherein the ridges of the first and second sets of gratings alternate.

89. The system of claim 88,

wherein the ridges of the first and second sets of grating include centerlines having a spacing between the centerlines of the ridges of the first and second sets of gratings; and

wherein the first and second sets of gratings are formed with the spacing between the centerlines uniform when the first and second masks are aligned without an overlay error.

90. The system of claim 74,

wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and

wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

91. The system of claim 90,

wherein the ridges of the first and second sets of gratings include centerlines, and

wherein the first and second sets of gratings are formed with the centerlines of the ridges aligned when the first and second masks are aligned without an overlay error.

92. The system of claim 74, wherein the periodic grating is formed from isotropic materials.

93. The system of claim 74, wherein the optical metrology system obtains the zero-order cross polarization measurements using an oblique and conical incident signal.

94. A system to obtain overlay measurements of a semiconductor wafer having a periodic grating with a first set of gratings and a second set of gratings, the system comprising:

an optical metrology system configured to:

obtain a first zero-order cross polarization measurement from a site on the periodic grating;

obtain a second zero-order cross polarization measurement from the same site on the periodic grating as the first zero-order cross polarization measurement; and

determine any overlay error associated with the formation of the first and second sets of gratings based on the obtained first and second zero-order cross polarization measurements.

95. The system of claim 94, wherein the optical metrology system includes:

a polarizer; and

an analyzer,

wherein the polarizer and the analyzer are set to a first angular setting to obtain the first zero-order cross polarization measurement, and

wherein the polarizer and the analyzer are set to a second angular setting to obtain the second zero-order cross polarization measurement.

99. The system of claim 94,

wherein the optical metrology system is configured to: compare the difference between the first zero-order cross polarization measurement and the second zero-order cross polarization measurement,

wherein an overlay error exists when there is a difference between the first and second zero-order cross polarization measurements.

101. The system of claim 94, wherein the periodic grating is formed from isotropic materials.

102. The system of claim 94, wherein the optical metrology system obtains the zero-order cross polarization measurements using an oblique and conical incident signal.

103. A computer-readable storage medium containing computer executable instructions for causing a computer to obtain overlay measurements for a semiconductor wafer, comprising instructions for:

obtaining zero-order cross polarization measurements from a periodic grating formed on the wafer,

wherein a first set of gratings of the periodic grating are formed on the wafer using a first mask, and

wherein a second set of gratings of the periodic grating are formed on the wafer using a second mask; and

determining any overlay error between the first mask and the second mask used to form the first and second sets of gratings based on the obtained zero-order cross polarization measurements.

104. The computer-readable storage medium of claim 103, wherein obtaining zero-order cross polarization measurements comprises:

obtaining a first zero-order cross polarization measurement; and

obtaining a second zero-order cross polarization measurement,

wherein the second zero-order cross polarization measurement has a polarization opposite that of the first zero-order cross polarization measurement.

106. The computer-readable storage medium of claim 104, wherein determining any overlay error comprises:

comparing the difference between the first zero-order cross polarization measurement and the second zero-order cross polarization measurement,

wherein an overlay error exists between the first and second masks when there is a difference between the first and second zero-order cross polarization measurements.

107. The computer-readable storage medium of claim 104 further comprising:

obtaining a set of first zero-order cross polarization measurements for a range of possible misalignments between the first and second masks; and

obtaining a set of second zero-order cross polarization measurements for a range of possible misalignments between the first and second masks.

108. The computer-readable storage medium of claim 107 further comprising:

generating a first response curve based on the set of first zero-order cross polarization measurements,

wherein the first response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of first zero-order cross polarization measurements; and

generating a second response curve based on the set of second zero-order cross polarization measurements,

wherein the second response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of second zero-order cross polarization measurements.

114. The computer-readable storage medium of claim 104, wherein the first zero-order cross polarization measurement includes TE polarization and the second zero-order cross polarization measurement includes TM polarization.

115. The computer-readable storage medium of claim 104, wherein the first zero-order cross polarization measurement includes TM polarization and the second zero-order cross polarization measurement includes TE polarization.

116. The computer-readable storage medium of claim 104, wherein the first and second zero-order cross polarization measurements are obtained from a single site on the periodic grating.

Appendix F
Interfering Claims of the 6,855,464 Niu et al. Patent

1. A method of obtaining overlay measurements, the method comprising:
forming a first grating test pattern using a first layer mask;
forming a second grating test pattern using a second layer mask, wherein the first and second grating test patterns have the same periodicity;
measuring the first and second grating test patterns using an optical metrology equipment; and
measuring the alignment of the second layer mask to the first layer mask based on the measurement of the first and second grating test patterns.

2. The method of claim 1, wherein grating lines of the second grating test pattern are formed on top of grating lines of the first grating test pattern.

3. The method of claim 2,
wherein a first distance measures a gap from a left edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern,
wherein the first grating line of the second grating test pattern is formed on top of the first grating line of the first grating test pattern.

4. The method of claim 3, wherein a second distance measures a gap from the right edge of the first grating line of the first grating test pattern to the right edge of the first grating line of the second grating test pattern.

5. The method of claim 2, further comprising:
forming one or more material layers between the first grating test pattern and the second grating test pattern.

6. The method of claim 1, wherein grating lines of the second grating test pattern are interlaced with grating lines of the first grating test pattern.

7. The method of claim 6,
wherein a first distance measures a gap from a right edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern,
wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern.

8. The method of claim 7,
wherein a second distance measures a gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern,
wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.

9. The method of claim 6, further comprising:

forming one or more material layers between the first grating test pattern and the second grating test pattern.

10. The method of claim 1, wherein the first and second grating test patterns include:
a first grating having grating lines in a first orientation; and
a second grating having grating lines in a second orientation perpendicular to the first orientation, wherein the second grating is adjacent to the first grating.

11. The method of claim 10, wherein the first and second grating test patterns include:
a third grating having grating lines in a third orientation, wherein the third orientation is 45 degrees relative to the first orientation; and
a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation, wherein the fourth grating is adjacent to the third grating and the second grating.

12. The method of claim 11, wherein the first, second, third, and fourth gratings are quadrants in a four-quadrant test pattern formed on a semiconductor wafer.

13. The method of claim 12, wherein measuring the first and second grating test patterns comprises:
measuring the first, second, third, and fourth gratings without rotating or reloading the semiconductor wafer.

14. The method of claim 13, wherein measuring the alignment of the second layer mask to the first layer mask comprises:
measuring the alignment in the first, second, third, and fourth orientations based on the measurement of the first, second, third, and fourth gratings.

15. The method of claim 1, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.

16. A method of obtaining overlay measurements, the method comprising:
forming a first grating test pattern using a first layer mask;
forming a second grating test pattern using a second layer mask,
wherein the first and second grating test patterns have the same periodicity, and
wherein the first and second grating test patterns have:
a first grating having grating lines in a first orientation, and
a second grating having grating lines in a second orientation perpendicular to the first orientation;
measuring the first and second grating patterns including the first and second gratings using an optical metrology equipment; and
measuring the alignment of the second layer mask to the first layer mask in the first and second orientations based on the measurement of the first and second grating patterns including the first and second gratings.

17. The method of claim 16,

wherein a first distance measures a gap from a left edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern,

wherein the first grating line of the first grating test pattern is formed on top of the first grating line of the second grating test pattern, and

wherein a second distance measures a gap from the right edge of the first grating line of the first grating test pattern to the right edge of the first grating line of the second grating test pattern.

18. The method of claim 16,

wherein a first distance measures a gap from a right edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern,

wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern,

wherein a second distance measures a gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern, and

wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.

19. The method of claim 16,

wherein the first and second gratings are formed on a semiconductor wafer, and

wherein the first and second gratings are measured using the optical metrology equipment without reloading the semiconductor wafer.

20. The method of claim 16, wherein the first and second grating test patterns include:

a third grating having grating lines in a third orientation,

wherein the third orientation is 45 degrees relative to the first orientation; and

a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation.

21. A structure formed on a semiconductor wafer for obtaining overlay measurements, the structure comprising:

a first grating test pattern formed on the semiconductor wafer using a first layer mask; and

a second grating test pattern formed on the semiconductor wafer using a second layer mask,

wherein the first and second grating test patterns have the same periodicity, wherein the first and second grating test patterns are measured using an optical metrology equipment, and

wherein the alignment of the second layer mask to the first layer mask is measured based on the measurement of the first and second grating test patterns.

22. The structure of claim 21, wherein grating lines of the second grating test pattern are formed on top of grating lines of the first grating test pattern.

23. The structure of claim 22, further comprising:

a first gap from a left edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern,

wherein the first grating line of the second grating test pattern is formed on top of the first grating line of the first grating test pattern; and

a second gap from the right edge of the first grating line of the first grating test pattern to the right edge of the first grating line of the second grating test pattern.

24. The structure of claim 22, further comprising:

one or more material layers formed between the first grating test pattern and the second grating test pattern.

25. The structure of claim 21, wherein grating lines of the second grating test pattern are interlaced with grating lines of the first grating test pattern.

26. The structure of claim 25, further comprising:

a first gap from a right edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern,

wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern; and

a second gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern,

wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.

27. The structure of claim 25, further comprising:

one or more material layers formed between the first grating test pattern and the second grating test pattern.

28. The structure of claim 21, wherein the first and second grating test patterns include:

a first grating having grating lines in a first orientation; and

a second grating having grating lines in a second orientation perpendicular to the first orientation,

wherein the second grating is adjacent to the first grating.

29. The structure of claim 28, wherein the first and second grating test patterns include:

a third grating having grating lines in a third orientation,

wherein the third orientation is 45 degrees relative to the first orientation; and

a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation,

wherein the fourth grating is adjacent to the third grating and the second grating.

30. The structure of claim 29, wherein the first, second, third, and fourth gratings are quadrants in a four-quadrant test pattern formed on the semiconductor wafer.

31. The structure of claim 21, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.

Appendix G
Comparison of the First Alternate of the Count to
Claim 18 of the '084 Patent and Claim 93 of the '153 Application

First Alternative of the Count	Claim 18 of the '084 Patent	Claim 93 of the '153 Application
18. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:	1. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:	78. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:
forming a periodic grating on the wafer having:	forming a periodic grating on the wafer having:	forming a periodic grating on the wafer having:
a first set of gratings,	a first set of gratings,	a first set of gratings,
wherein the first set of gratings are formed on the wafer using a first mask, and	wherein the first set of gratings are formed on the wafer using a first mask, and	wherein the first set of gratings are formed on the wafer using a first mask, and
a second set of gratings,	a second set of gratings,	a second set of gratings,
wherein the second set of gratings are formed on the wafer using a second mask,	wherein the second set of gratings are formed on the wafer using a second mask,	wherein the second set of gratings are formed on the wafer using a second mask,
wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;	wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;	wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;
selecting a wavelength;	selecting a wavelength;	
measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer using the selected wavelength; and	measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer using the selected wavelength; and	measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer; and

First Alternative of the Count	Claim 18 of the '084 Patent	Claim 93 of the '153 Application
determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal;	determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.	determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.
	12. The method of claim 1 further comprising:	88. The method of claim 78 further comprising:
generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,	generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,	generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,
wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments,	wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.	wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.
wherein the determining the misalignment between the first and second sets of gratings comprises:	18. The method of claim 12, wherein the determining the misalignment between the first and second sets of gratings comprises:	93. The method of claim 88, wherein the determining the misalignment between the first and second sets of gratings comprises:
comparing the measured diffraction signal to the generated set of diffraction signals; and	comparing the measured diffraction signal to the generated set of diffraction signals; and	comparing the measured diffraction signal to the generated set of diffraction signals; and
determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.	determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.	determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.

Appendix H
Comparison of the Second Alternate of the Count to
Claim 18 of the '084 Patent and Claim 93 of the '153 Application

Second Alternative of the Count	Claim 18 of the '084 Patent	Claim 93 of the '153 Application
93. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:	1. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:	78. A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:
forming a periodic grating on the wafer having:	forming a periodic grating on the wafer having:	forming a periodic grating on the wafer having:
a first set of gratings,	a first set of gratings,	a first set of gratings,
wherein the first set of gratings are formed on the wafer using a first mask, and	wherein the first set of gratings are formed on the wafer using a first mask, and	wherein the first set of gratings are formed on the wafer using a first mask, and
a second set of gratings,	a second set of gratings,	a second set of gratings,
wherein the second set of gratings are formed on the wafer using a second mask,	wherein the second set of gratings are formed on the wafer using a second mask,	wherein the second set of gratings are formed on the wafer using a second mask,
wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;	wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;	wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;
	selecting a wavelength;	
measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer; and	measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer using the selected wavelength; and	measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer; and

Second Alternative of the Count	Claim 18 of the '084 Patent	Claim 93 of the '153 Application
determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal;	determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.	determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.
	12. The method of claim 1 further comprising:	88. The method of claim 78 further comprising:
generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,	generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,	generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,
wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments,	wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.	wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.
wherein the determining the misalignment between the first and second sets of gratings comprises:	18. The method of claim 12, wherein the determining the misalignment between the first and second sets of gratings comprises:	93. The method of claim 88, wherein the determining the misalignment between the first and second sets of gratings comprises:
comparing the measured diffraction signal to the generated set of diffraction signals; and	comparing the measured diffraction signal to the generated set of diffraction signals; and	comparing the measured diffraction signal to the generated set of diffraction signals; and
determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.	determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.	determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.